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Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

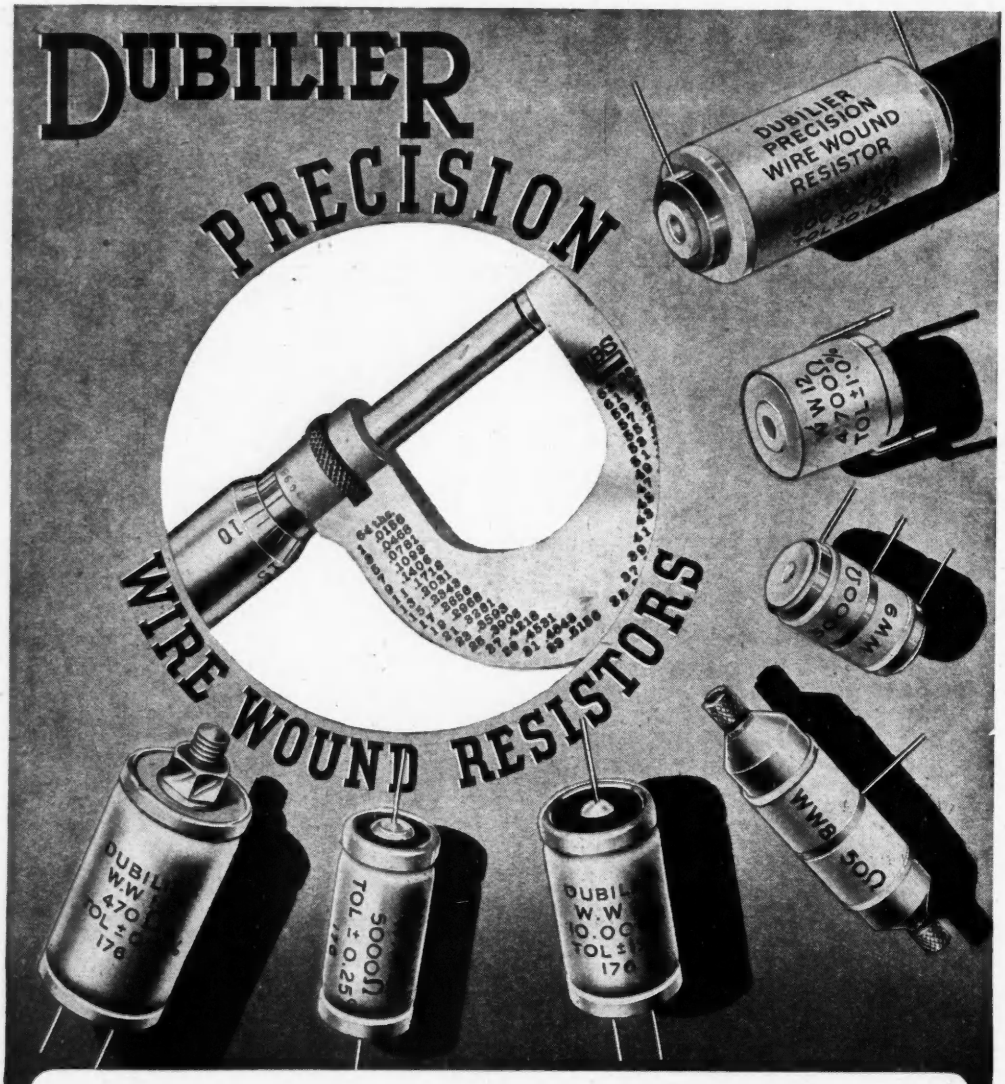
High Power Television Transmitters
Some Aspects of Their Design — Part 1

Amplitude-Modulated Communication in the V.H.F. Band

Velocity Modulation

A Modern Vibration Measurement Laboratory — Part 3

2/- MAY, 1947



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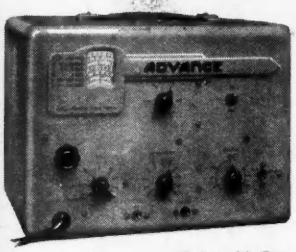

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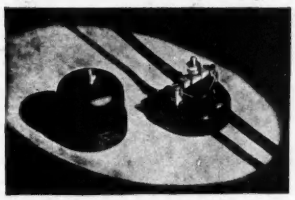

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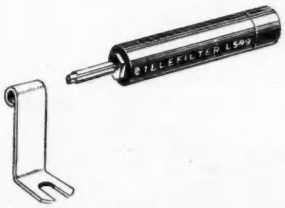

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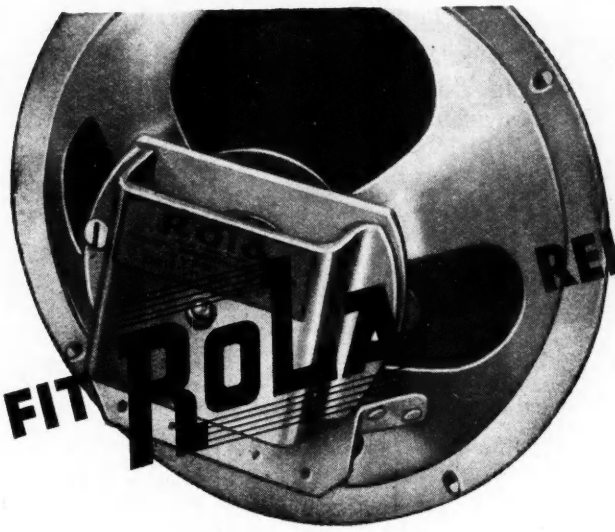

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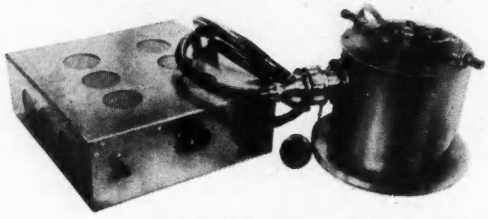

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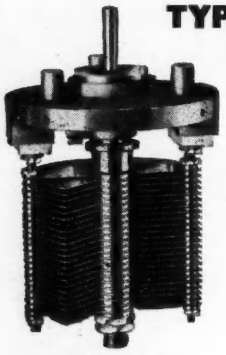

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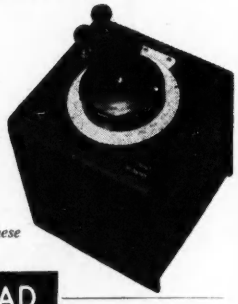

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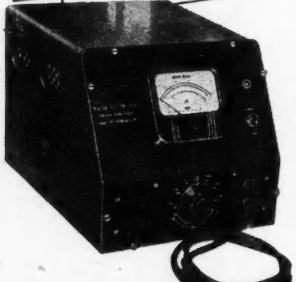

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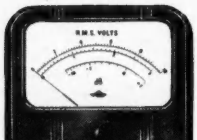

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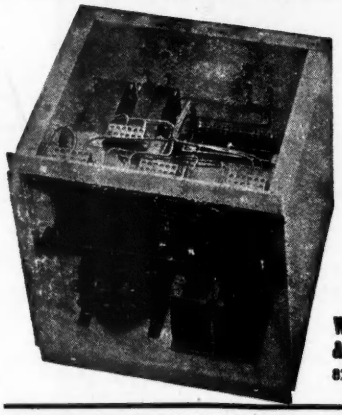

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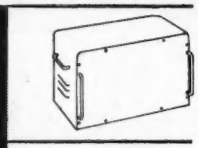
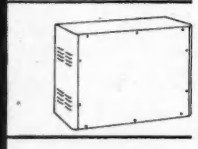
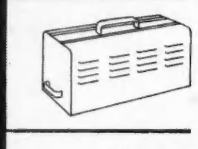
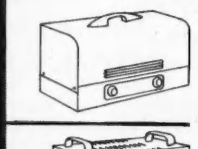

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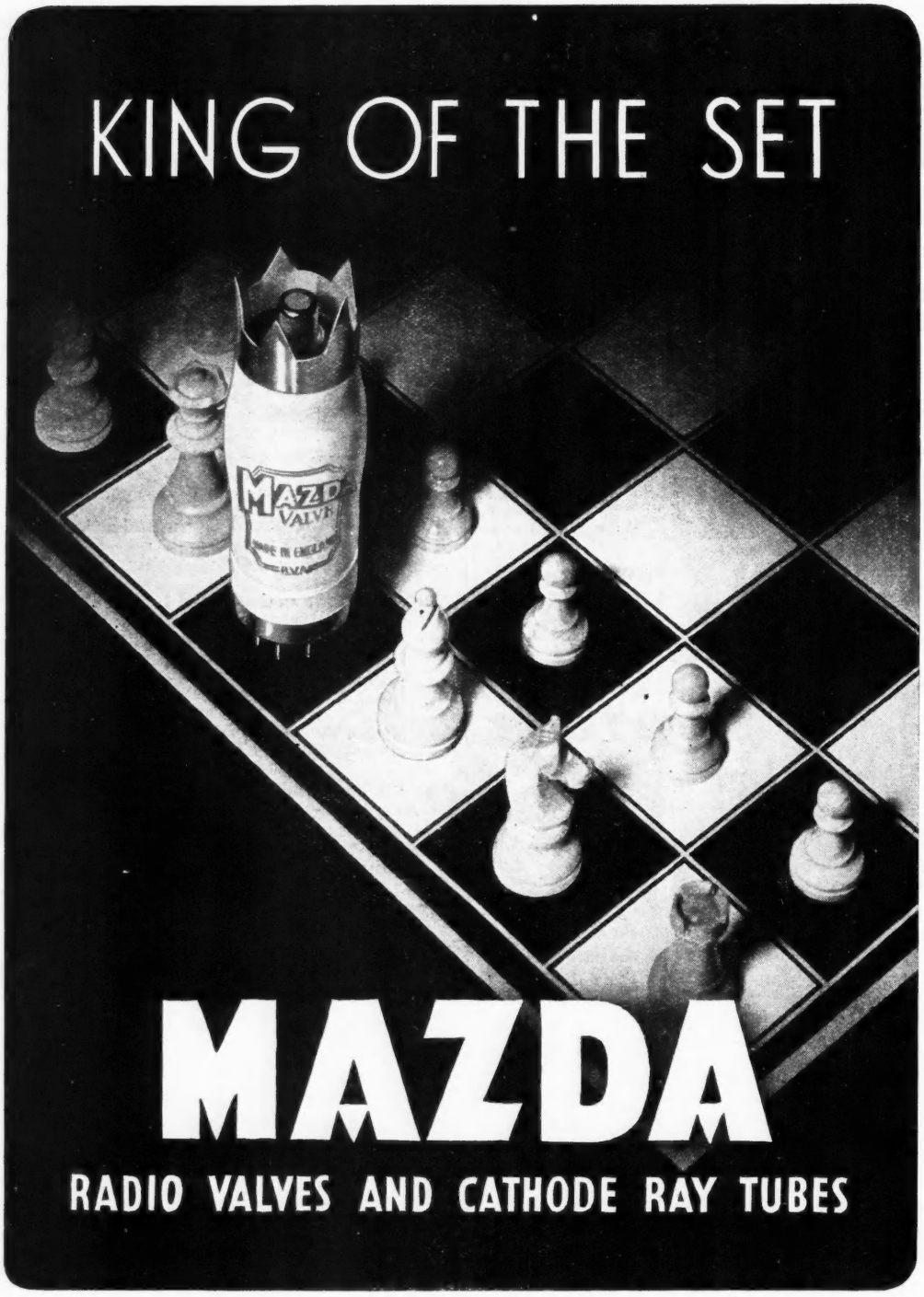

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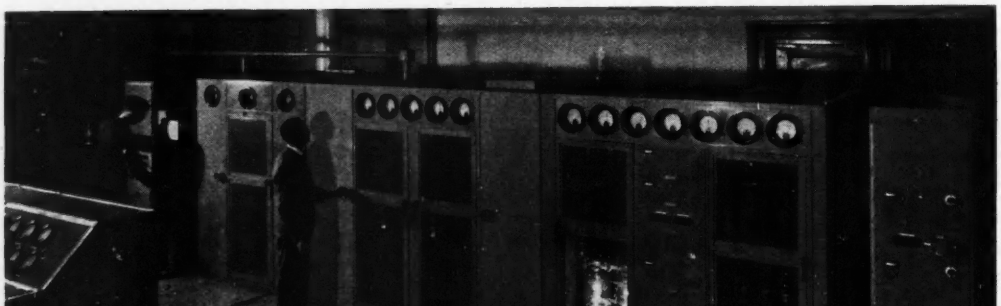


High Power Television Transmitters

—*Some Aspects of their Design*

By P. A. T. BEVAN, B.Sc., A.M.I.E.E.*

THE reopening of the London Television Service at Alexandra Palace and the recommendation to extend the service to some of the larger provincial centres means that radio engineers are again considering ways of overcoming the unique circuit and valve problems encountered in the design of ultra short-wave television transmitters operating at frequencies in the neighbourhood of 50 Mc/s. or higher. Transmitters are likely to be required, both at home and abroad, having R.F. power outputs of between 25 to 50 KW peak at full modulation and capable of being effectively modulated with picture and synchronising signals involving a band width of at least ± 2.75 Mc/s. and possibly ± 5 Mc/s. if the present standards of picture definition are increased.

Wartime developments in radar transmitters have not assisted to any great extent in the television field, as although peak pulse powers of many hundreds of kilowatts are now obtainable, the pulses are of very short duration and the capabilities of the valves and circuits used are still of the order of a few kilowatts only when considered for CW working.

The valve problem still remains the principle obstacle in the design of ultra-short-wave television transmitters with peak output powers of 50 KW and upwards as most of the limitations encountered are directly due to the relatively large physical size of the valves at present available. This applies particularly to high-power wide-band modulated stages where water-cooled valves are virtually essential because the anode dissipation may well be of the same order as the peak power output. The practical construction of such valves involves the use of glass envelopes of relatively long dimensions which implies that the grid and filament leads are themselves of appreciable length in terms of the operating wavelength.

This has a considerable bearing on the stabilising of the valves and circuits, particularly if a fair range of operating carrier frequencies is required. The inductance of these leads coupled with the presence of the inter-electrode capacities results in standing waves on the leads and if the operating frequency were increased until the effective length of the leads internal to the envelope became more than a quarter-wavelength long the voltage nodes would occur inside the envelope.

This state of affairs is unlikely in a practical design, but nevertheless the reactance of the filament leads will be significant, and since it is common to both the plate and grid circuits it makes stabilising difficult if the filament is earthed directly. The use of push-pull circuits which, for reasons mentioned later, are generally favoured for an ultra-short-wave transmitter, provide a convenient method of overcoming this particular difficulty since they permit the filaments of the two valves to be connected together through an adjustable copper tube "trombone," the "slider" or shorting bar of which is placed so that it is a half-wavelength away from each actual cathode and hence behaves as a direct non-reactive connexion between the cathodes.

* Design and Installation Department, The British Broadcasting Corporation.

The photograph above shows the modulator section of the A.P. Television transmitter—*B.B.C. photograph.*

The inductance of the relatively long internal grid lead may also cause difficulty in grid-to-anode neutralising as capacity compensation external to the grid terminal by means of grid-reactance capacitors may still leave an appreciable amount of free grid reactance, and to obtain stability over reasonable operating frequency band (or even over the modulation frequency band) somewhat heavy loading of the grid circuit has to be resorted to. Recent advances in the design of very short single ended water-cooled valves for short-wave operation with low reactance electrode connexions will have done much to minimise these effects for frequencies of the order of 50 Mc/s.

The inter-electrode capacities of the larger valves present very low reactances at this frequency which results in abnormally high currents in the electrodes, seals and leads. The R.F. resistance and dielectric losses in these parts cause appreciable heating and in high-power stages necessitate the use of additional air cooling, particularly for the glass seals.

The inter-electrode capacities do not in themselves impose many serious limitations on stabilising except in so far as a large-anode-to-grid capacity makes the physical size of the neutralising condensers rather large, so that it is difficult to keep the connecting leads short and the stray capacities suitably low. In the case of television transmitters the most important limitation imposed by the inter-electrode capacities relates to their effect on the peak power output of the final amplifier and its band-width, since these capacities together with any neutralising capacities virtually determine the load resistance which must be referred at the anode of the valve for any given band-width response of the output tank and coupling circuits. With the present B.B.C. standards of picture definition the tank and output coupling circuits are required to pass modulation frequencies from zero up to 2.75 Mc/s, without significant loss at the higher frequencies so that "maximally flat" coupled circuits of low Q are essential. For the tank circuit the minimum value of parallel C is fixed by the above capacities which also fix L for a given carrier frequency and hence also determine the minimum value of the referred series load resistance in this circuit for the required circuit Q_s and band-width response. This in turn fixes the maximum value of parallel load resistance into which the valve works, and hence determines its maximum power output.

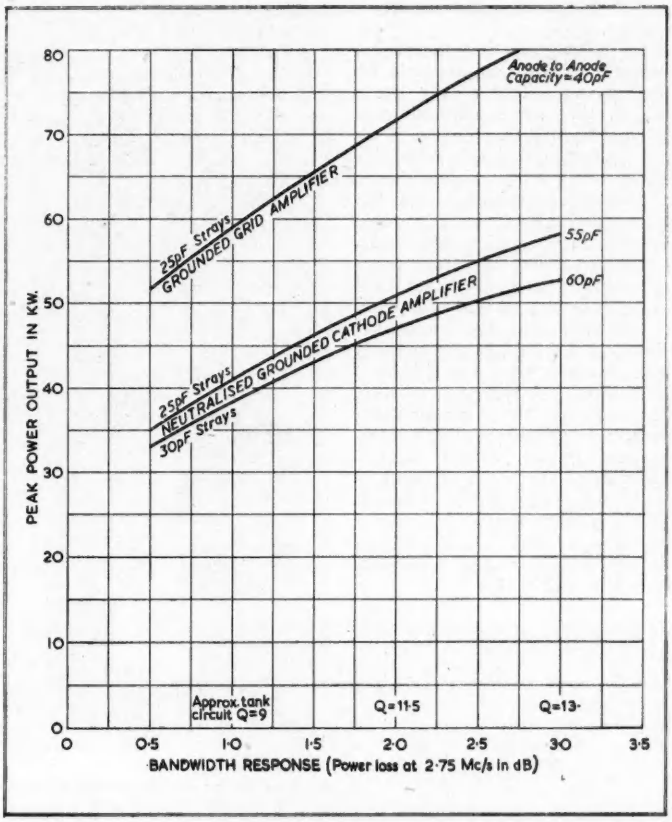


Fig. 1.—Curves showing estimated peak R.F. power output in terms of the band-width response, at a modulation frequency of 2.75 Mc/s., for a pair of grid modulated output valves of the CAT. 21 class, assuming a filament emission of 25 amperes, but ignoring limitation of output due to permissible anode dissipation. Frequency, 50 Mc/s. A critically coupled bandpass output circuit is assumed in which Q tank = 2 Q secondary.

In general the necessity for a wide band-width implies that the valve is called upon to operate as a constant current generator into an abnormally low anode load resistance and hence for a given peak emission the peak power output is also limited to a value considerably lower than would otherwise be the case. At the same time the maximum useful anode voltage swing is limited by the low load resistance so that the maximum useful D.C. anode voltage is also limited, which results in a relatively poor anode conversion efficiency, usually amounting to not more than 45 to 50 per cent. in practice for band-widths of the order of −1 db. at 2.75 Mc/s.

If the band-width required is increased it can only be done at the expense of peak power output from a valve of given filament emission and inter-electrode capacities. This is a fundamental relationship and increasing the carrier frequency in relation to the band-width does not materially assist the problem, a point to be borne in mind when higher standards of picture definition are being considered. The curves in Fig. 1 indicate the way in which the peak power output obtainable from valves of a given filament emission and anode-to-anode capacity falls as the band-width response is increased. The curves are approximately applicable to a pair of valves of the CAT.21 class operating in a push-pull circuit at 50 Mc/s., but ignore the limitation in power output

due to the maximum allowable anode dissipation.

It may be argued that the higher frequency sidebands do not call for the full power output of the transmitter, so that some discrimination against the higher frequencies in the radio frequency circuits is allowable and the frequency characteristic could be compensated and made flat over the required range by suitable equalisation in the vision modulator. Such compensation, however, tends to introduce phase distortion and reflexions (ringing) so that in general it is desirable that the modulated amplifier itself should have a sensibly flat characteristic over the side-band range required. A survey of existing British and American transmitting valves commercially available indicates that if an overall amplitude/frequency response having a tolerance not exceeding −2 db. at 2.75 Mc/s. is required, (proportioned equally between the modulator and modulated amplifier) the maximum output power obtainable from a pair of grid-modulated water-cooled triodes operating at 50 Mc/s. is at present limited to some 35 to 40 KW peak when modulated by the standard B.B.C. 405-line television service waveform equivalent to an all-white picture.

Fig. 2 shows a recent British valve, the CAT.21, which is one example of the class of output valve showing the greatest promise for television transmitters with power outputs of this order. It is interesting to compare the construction of this valve with its counterpart of eleven years ago, the CAT. 9 shown in the same photograph. This was the type round which the grid-modulated output stage of the vision transmitter at the London Television Station was designed and the maximum output attainable from a pair of these valves at 45 Mc/s. for an amplitude/frequency response falling by approximately 2 db. at 2.5 Mc/s. was 17 KW peak. Fig. 3 gives a view of the output stage of the transmitter concerned. A comparison of the approximate characteristics of CAT.21 and CAT.9 is given in Table 1.

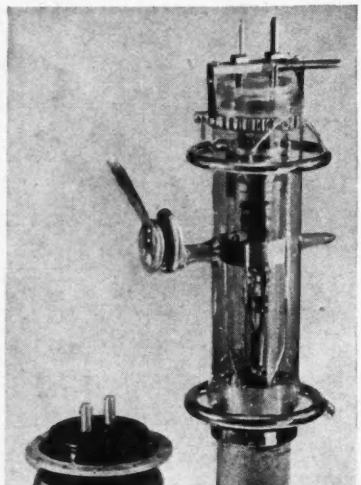


Fig. 2.—A side by side comparison of the recent CAT 21 water-cooled short-wave transmitting triode (*left*) and the older CAT. 9 (*right*). The new valve is capable of giving approximately twice the output power of its earlier counterpart for wide band television transmission. Its overall height of 14 inches is approximately the same as the anode length only of the CAT. 9.

(Photograph by courtesy of M. O. Valve Company Limited

TABLE 1
Comparison of Operating Characteristics for New CAT 21 and Earlier CAT 9 Valves

Characteristics	CAT 9	CAT 21
Filament volts	18-20 v.	13 v.
Filament current ...	100 a.	320 a.
Anode volts (Max.)* ...	15 KV.	10 KV.
Peak emission current (90% saturation) ...	12 a.	25 a.
Maximum anode dissipation	18 KW.	20 KW.
Amplification factor ...	45	20
Capacitance—		
grid-to-anode	17.6 $\mu\mu$f.	30 $\mu\mu$f.
anode-to-filament ...	16.0 ,,	1.1 ,,
grid-to-filament ...	29.2 ,,	39 ,,

* Permissible operating anode voltage at 50 Mc/s. 6 KV. approx.

Transmitter Component Construction

At carrier frequencies of 50 Mc/s. and above where wavelengths reduce to a few metres, quarter- and half-wave line sections become of reasonable physical dimensions and can conveniently be used as impedance transformers or inverters, reactances, insulators or short circuits, and harmonic filters of high Q.

Sections of line composed of parallel tubular conductors less than a quarter-wave long and having either open or short-circuited terminations are an efficient and inexpensive form of reactance and are useful as adjustable tank circuits inductance for the high-power stages where large circulating currents occur. The conductor material should be high-conductivity annealed copper, preferably silver plated to reduce skin resistance.

Capacitors, particularly variable capacitors, of the type used in medium-wave transmitters are unsuitable not only because their minimum capacity is invariably too high, but also because their mechanical construction usually lacks the simplicity required for U.S.W. application. Plain tubular concentric air dielectric capacitors, a simple pair of adjustable circular disks or hinged plates which can be mounted directly on the valve assemblies with very short connexions are the most suitable types for providing such adjustments of the circuit and valve capacities as may be required for tuning purposes.

The impedance levels of the R.F. circuits are invariably much lower than in medium-wave design so that the reactance of coupling and blocking capacitors must be extremely low if they are not to upset the circuit operation.

The design of such capacitors presents a difficult problem as obviously their capacity must be relatively high, which requires large physical size, while their losses (which include eddy current as well as dielectric losses) must be kept at a minimum since they will inevitably be called upon to pass high currents of the order of 100 amperes or more.

Air-dielectric capacitors are undoubtedly the most reliable, but are rarely convenient for use as coupling or blocking capacitors owing to their large bulk.

Capacitors constructed from a series of circular copper plates interleaved with thin high-grade mica sheet have been used with some success for grid and anode blocking, but unless great care is taken in their construction overheating due to eddy current losses is likely to result. Increasing the cooling surface by finning may not give the desired temperature reduction, the additional radiation being offset by an increase in eddy current heating. Insulation of the R.F. circuits still presents a problem, as although a great many new forms of insulating material have become available they all suffer from some disadvantage. Many are thermoplastic and their dielectric constant is such that they pass a considerable current which, in spite of a good power factor, produces sufficiently

severe internal heating to cause mechanical distortion. Further, certain of the synthetic types are virtually destroyed by a flashover which from the operational point of view is a serious disadvantage.

Composite insulators of mica and glass or straightforward porcelain or pyrex glass still seem to be the most generally accepted types. Corona shields at the high potential end of the insulator to distribute the field over the external surface of the insulator are a virtual necessity. Any concentration of the field within the insulator such as would result from metal studs screwed into the body of the insulator produces severe overheating and such a construction should be avoided.

The resistors used for grid damping and grid and anode stabilising require careful choice. Wire-bound resistors are unsuitable owing to their high inductance while the capacity of the non-inductive carbon types becomes significant at frequencies above about 30 Mc/s. The problem of a satisfactory test load for television transmitters, or for that matter any ultra-short-wave transmitter, has yet to be solved if a power dissipation of the order of 50 KW is involved. Possible forms of test load are a dissipative line or a parallel-tuned circuit using a resistive inductance element constructed in tubular form through which cooling water is circulated. The design is more difficult for the television case as the impedance of the load should remain substantially constant and non-reactive over the modulation band width concerned.

In an ultra-short-wave television transmitter of the high-power grid-modulated type which uses an R.F driver stage of conventional form, the grid loading of the modulated output stage is a special problem as the grid loading resistors will be required to dissipate a far greater power than is the case with medium-wave sound transmitters.

In order to obtain a high degree of linearity over the whole amplitude range of the vision signal the R.F. impedance presented by the grids must be kept sensibly constant between modulation limits corresponding to the tips of the synchronising signals and peak of the picture signal. In medium-wave transmitters a high ratio of power absorbed by the grid circuit to power absorbed by the grid loading resistances (about 1 to 10) is achieved without dissipating a great deal of power in the resistances because the grid circuit power is relatively small.

In the ultra-short-wave case, however, a large proportion of the total exciting power is absorbed by the grid circuit and transferred to the anode circuit, mainly due to electron transit time in the valve, and to obtain satisfactory constancy in grid impedance the grid loading resistances are also called upon to dissipate a relatively large amount of power. A typical case is the 45 Mc/s. 17 KW peak transmitter at the London Television Station where the modulated amplifier grid circuit absorbes about 1.5 KW. Obviously a 1 to 10 ratio of grid circuit power to grid loading power is out of the question in such cases as it would mean a total driving power greater than that delivered to the aerial.

In general, ratios of 1 to 3, or even lower, have to be tolerated for economic reasons, but even so a grid load comprising a bank of non-reactive resistors capable of dissipating some 6 to 8 KW would be required for a transmitter having an output of the order of 50 KW peak.

To reduce the bulk of the grid load assembly the provision of an efficient air-cooling system is essential. Tubular resistance elements with air blown down the centre give a convenient arrangement for cooling. Tubes of low resistance connected in series are generally the most satisfactory and with a series connexion the effect of their capacitance can be offset and their loading equalised by suitably grading the tube resistances so that their value is lower at the grid (or high potential) end than at the low potential end.

The low ratio mentioned above inevitably results in a significant amount of "bottom-bending," but with positive modulation this does not greatly matter as it is the synchronising signals only which are reduced in amplitude and subject to non-linear amplication.

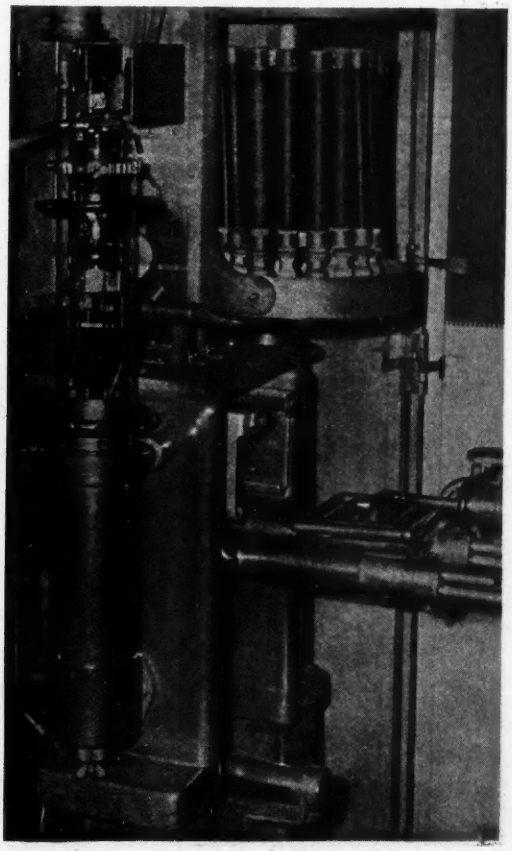


Fig. 3.—A view of the modulated amplifier output stage of the eleven-year-old vision transmitter at the London Television Station which gives an output of 17 KW. peak using a pair of CAT. 9 valves. The output coupling circuit can be seen on the right and the grid load at top centre.

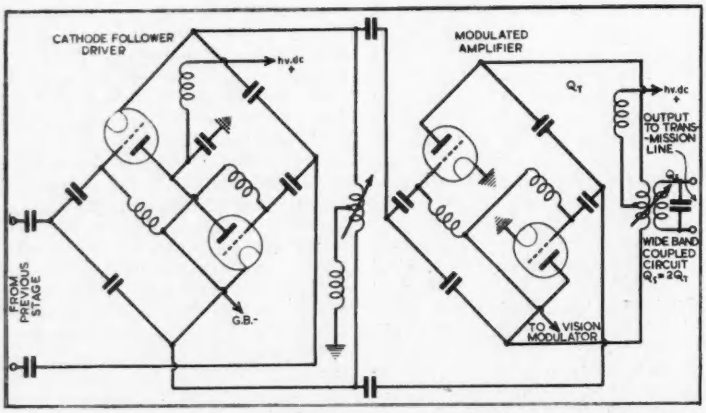


Fig. 4.—Wide band modulated R.F. amplifier driven by R.F cathode follower driver stage

The use of an R.F. cathode follower driver stage for the final modulated amplifier (as shown in Fig. 4) might well provide a solution to the general problem of grid loading. The low output impedance and good voltage regulation of such a driver should enable it to deal effectively with the variation in the grid input impedance of the modulated amplifier over the vision modulation cycle without the addition of a large and wasteful grid load, and consequently should enable a significant reduction in the total driving power to be achieved.

The filaments of the driver stage are at high R.F. potential, but could probably be A.C. heated via insulating transformers without giving rise to excessive hum modulation. The permissible figure for the visible non-synchronous hum is approximately −45 db. below the full white picture signal, at 100 c/s., and in general necessitates D.C. heating for valves with directly heated cathodes unless the stage gain is low as in the case of a cathode follower.

The accurate measurement of the current in the R.F. circuit is a problem yet to be solved. For normal service as well as testing, reliable meter indication of the current in the tank circuit and the output feeder are necessary, but little reliance can yet be placed on the accuracy of standard commercial thermo-couple ammeters at frequencies above 10 Mc/s. and current much above 30 amperes.

In addition to the inaccuracy of the thermo-couple the direct introduction of meters with high current couples inevitably disturbs the circuit impedance so that instruments operated from current transformers in which the current conductor acts as a bar primary are preferable.

This is normal practice in medium wave transmitters for currents above 20 amperes, but so far no transformers suitable for frequencies of 50 Mc/s. have yet been developed.

(To be continued)

An Elegant Service Bench

The photograph shows an all-metal service and test bench manufactured by "Télémesure" of Lyons, France. The upper rack contains a full range of test instruments mounted on removable racks. Among these can be seen a test oscilloscope, universal test-meter with 48 ranges and provision for resistance and capacitance measurement, and signal generator. A row of sockets is at the back of the bench, and below, on the supports, are drawers for components and tools.

P. Hémardinquer, Grenoble—

Amplitude-Modulated Communication in the V.H.F. Band

By D. H. HUGHES, A.M.I.E.E.*

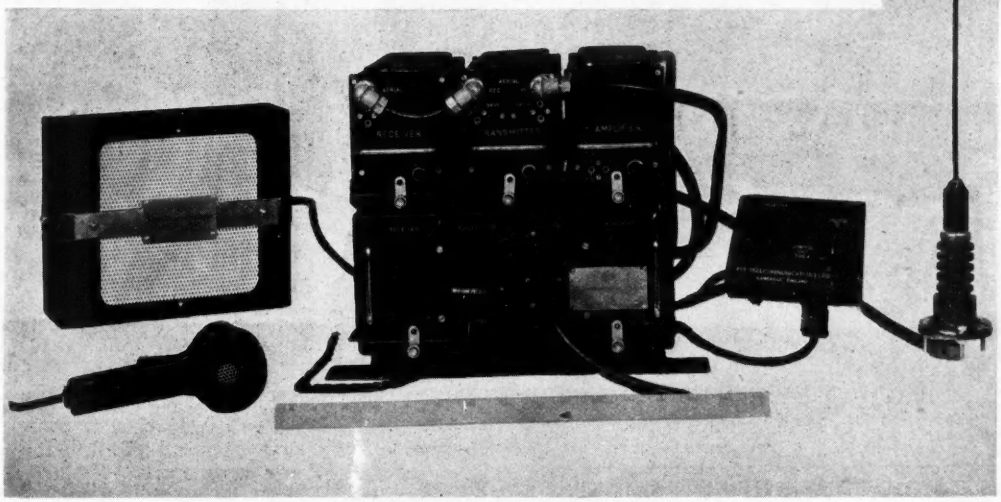


Fig. 1. New A.M. mobile equipment described in the article.

MUCH has been published during the last few years to justify the use of frequency modulation, particularly on the V.H.F. band for communications, and it is true that for some time it had many advantages over amplitude modulation for this purpose. Recently, however, considerable advances have been made in the design of A.M. equipment, so that it is now able again to compete effectively with F.M. It is the purpose of this article to make a fresh assessment of the relative merits of the two systems, and to illustrate the improved technique in A.M. by giving a description of some equipment which has recently been developed for commercial use, together with a brief account of some of the results obtained with it.

Requirements of Communication Systems

A recent article by E. P. Fairbairn[1] describes the requirements of a police communication system. It is there mentioned that the mobile transmitter radiates 5-10 watts, while the control station may employ a 100-watt transmitter. This practice has become fairly standard, since the control station can generally be sited where the ambient noise level is low, while the cars have to operate in urban areas where there is a high level of interference. The object is, therefore, to lay down a high level of signal from the fixed transmitter, using a relatively insensitive mobile receiver, while the much weaker signal from the mobile transmitter can be received equally well at the fixed station due to the lower noise level at the latter.

In other instances, however, particularly in the case of commercial users, it is not always possible to choose an ideal site for the control station, which often has to be installed in a city office building; the expense of a 100-watt transmitter can also be an objection. In these cases, the noise level is likely to be of the same order at both fixed and mobile sets, and there is then no point in using a higher power at the fixed transmitter, which can be of the same type as the mobile transmitter. Field tests have confirmed these conclusions: similar ranges in both directions have been obtained employing either a 100-watt fixed transmitter outside a town or a 12-watt transmitter in a town, while, with a 100-watt fixed transmitter in a town, the mobile-to-fixed transmission became unuseable before the fixed-to-mobile; in all cases, the mobile transmitter was radiating 12 watts and the fixed receiver was at the same location as the fixed transmitter.

The requirements for the receivers are high sensitivity and good signal/noise ratio, an efficient noise limiter to overcome impulsive interference, a squelch circuit to suppress random noise in the absence of a signal, and an A.V.C. system which is both level over a wide range of signal input and very fast in action to overcome flutter fading when the car is in motion.

Relative merits of F.M. and A.M.

It has been the custom to regard F.M. receivers as being generally more sensitive than A.M. receivers, but it is possible to make equally sensitive A.M. receivers without any difficulty. Absolute sensitivity is of no value once it is better than a few microvolts, unless the signal/noise ratio is adequate, and this is the only criterion for judging the usefulness of a receiver on weak signals. As an indication of what is now possible with A.M., a receiver for frequencies between 80 and 100 Mc/s., employing one R.F. amplifier, has been designed with signal/noise ratios of 10 db. for

* Pye, Ltd.

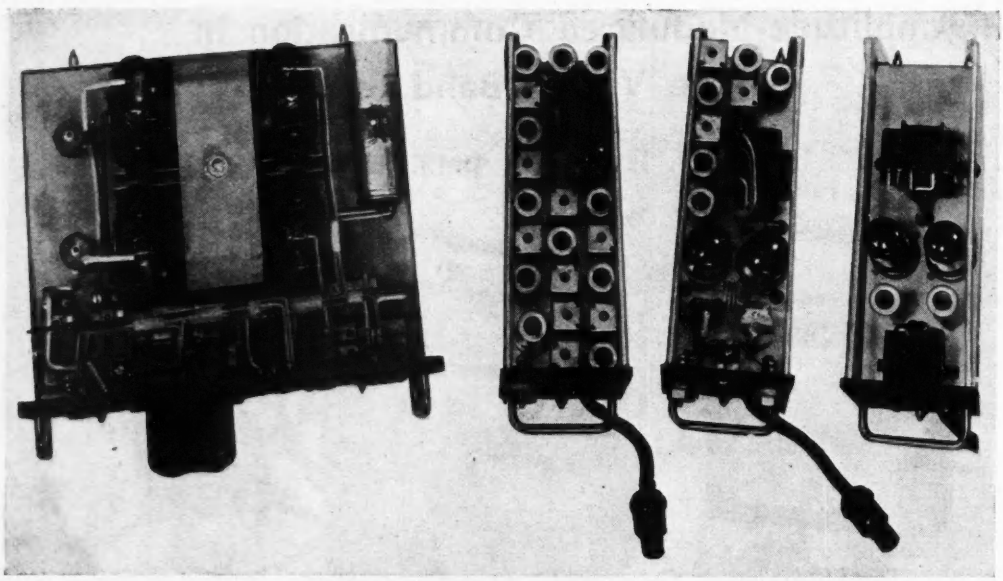


Fig. 2. View of chassis of power unit, receiver, transmitter and amplifier, used in equipment shown in Fig. 1.

1.5 μV and 20 db. for 5 μV input, while one with two R.F. amplifiers has the same ratios for inputs of approximately ½ μV and 2 μV respectively. In operation, the signal/noise ratio must, of course, take into account the response of the receiver to external noise fields; these are of two types, impulsive and random. While F.M. gives very good suppression of impulsive noise, in an A.M. receiver fitted with an efficient noise limiter this type of interference can also be reduced to such an extent that even very weak signals are not obscured by it. So far as random noise is concerned, A.M. is not as good as F.M. when the signal input is between roughly 2 and 10 times the noise input; with stronger signals, the performance of either is perfectly adequate, and any difference between them is immaterial; with weaker signals, F.M. deteriorates until it is no better than A.M.[3] In practice, it is found that A.M. is little inferior to F.M. so far as readability of signals is concerned, although A.M. has rather more background noise over a certain range of signal strength. By restricting the audio-frequency response to the speech band of 300 to 3,000 c/s., and by using pre-emphasis at the transmitter and de-emphasis at the receiver, the signal/noise ratio of both systems can be considerably improved. With a very sensitive receiver of either type, it is necessary to include a squelch circuit to suppress the noise in the absence of a signal, and this can be done equally well with either A.M. or F.M.

Considering now the A.V.C. action, this is effected extremely well by the limiter in an F.M. receiver. In an A.M. receiver, an equally level output can be obtained by controlling an A.F. stage in addition to the R.F. and I.F. stages, and there is no difficulty in obtaining a time constant for the A.V.C. circuit as short as 20 milliseconds when the bass response can be cut below 300 c/s.: this is quite fast enough to cope with the most rapid fading.

So far as the transmitter is concerned, the advantage usually claimed for F.M. is that the power input to the final stage is half that required for the same power output on A.M. This is the case when 100 per cent. modulation is occurring, but, in speech transmission, the average modulation is very much less than 100 per cent. Since the number of mobile transmitters is very much greater than the number of high-power fixed transmitters, considerations affecting the former are the more important. In this type of equipment, it is usual with A.M. to employ an anode-modulated class C power amplifier. The input to this from the D.C. power supply is of the same order as for an equal R.F. power output using an F.M. transmitter, and the extra power input for the sideband energy is obtained at A.F. from the modulator. It is possible that in some cases the rather lower average power dissipation in an F.M. stage would enable a smaller valve to be used, but, as the number of types of valves available is limited, this is by no means always the case. For example, in the equipment described later in this article, the H.T. supply was determined by the availability of a standard machine, and the output valves used are run sufficiently below their maximum rating to handle the average modulation power with safety, but, in an F.M. equipment of similar rating, the same machine and valves would be used because they are the nearest available to the required size. This leaves F.M. with the advantage that a low-power modulator can be used, but there are two factors to be taken into account to offset this point: one is that, for police and many other uses, it is frequently desirable to include public address equipment with the radio set, and an anode-modulation amplifier is ideal for this purpose, the only additional item required being the P.A. loudspeaker. The other factor is that, with an F.M. transmitter employing phase modulation, it is necessary to start with a crystal oscillator on a frequency of the order of 1 Mc/s. (for a signal frequency of 80 Mc/s.), whereas with A.M. the initial frequency is limited only by the availability of crystals and may be of the order of

10 Mc/s. or more. Thus more stages of multiplication are required with F.M., so partially offsetting the larger modulator required for A.M.

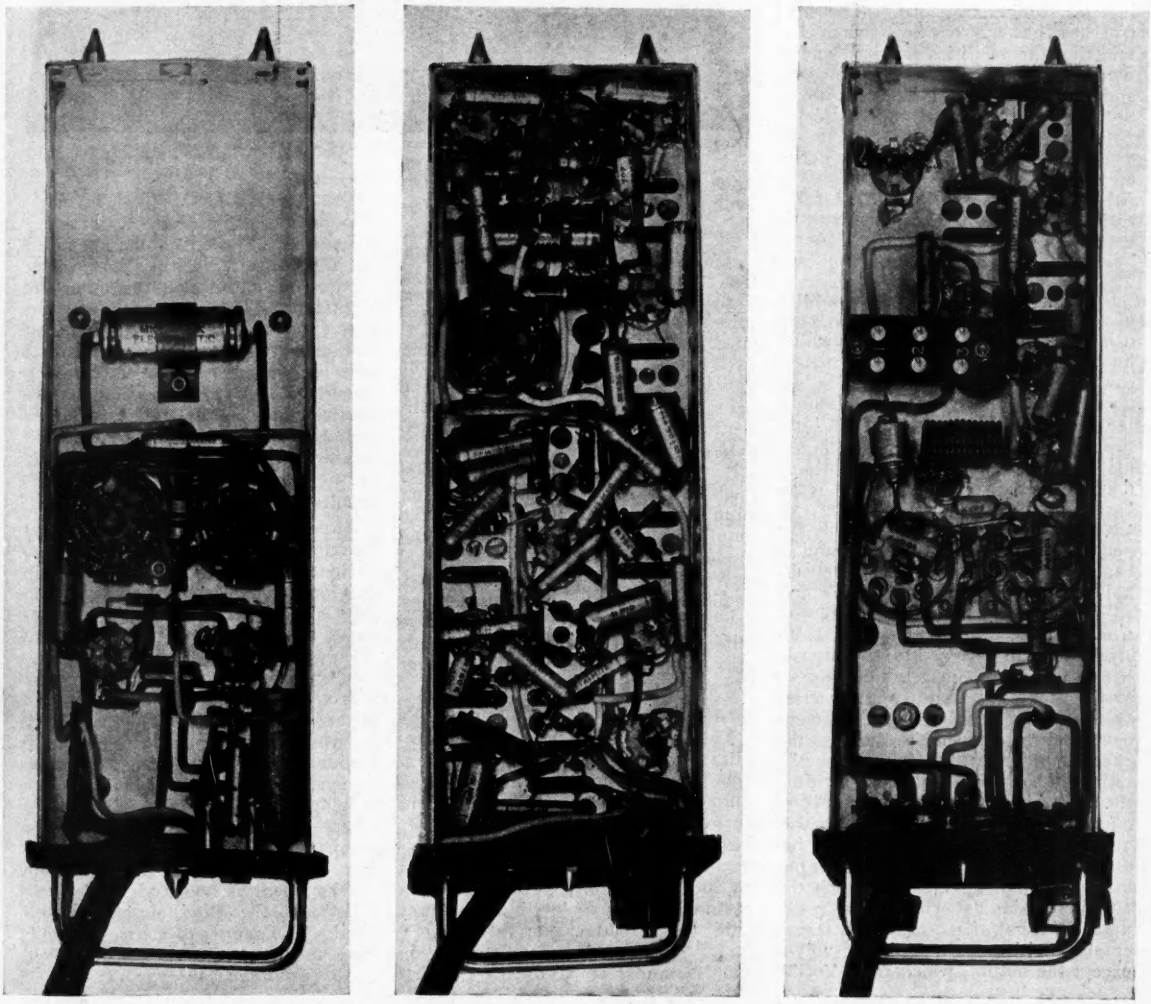
Up to now in this discussion, the advantage appears to lie slightly in favour of F.M., but there are certain other factors to be taken into account which favour A.M. and which, in the opinion of the author, are sufficient to sway the balance. In considering the receiver response to noise, it was assumed that all circuits were correctly in tune, but if, due to oscillator drift or misalignment of the discriminator circuits, this should not be the case, then F.M. receiver performance deteriorates badly, both noise response and distortion being seriously increased. This is not the case with A.M. as the I.F. pass-band has to be many times wider than is necessary to accommodate the signal bandwidth, in order to permit efficient operation of the noise limiter. Apart from this, F.M. circuits are more complex than A.M., and the technique required for handling them is not so widely known. Thus F.M. is likely to make much greater demands on maintenance personnel, and the performance of F.M. equipment after it has been in service for some time is less likely to be up to standard. Taking a long view, it therefore seems probable that in most cases A.M. would prove a better investment than F.M.

No mention has yet been made of systems using a number of fixed transmitters for covering large areas. So far, this has only proved successful with A.M.,[3] but it may yet prove possible to evolve a similar system using F.M.

New A-M Mobile Equipment

To illustrate the trend of modern practice in A.M. equipment, it may be of interest to describe a set which has recently been developed by Pye, Ltd. This has been used successfully for a wide variety of purposes, such

Fig. 3. Under-chassis view of receiver, transmitter and amplifier.



as police and fire services, taxis and public transport, tugs, etc. It is constructed throughout using miniature technique, and the photographs give a good idea of its compactness. The set itself occupies a space of less than one cubic foot and weighs approximately 40 lb. It consists of four separate units assembled on a cradle mounted on shock absorbers: on the top tray are the receiver, transmitter and speech amplifier, each of which can be taken off by removing the plug-in connectors and undoing one nut, and below these is the power unit, which is held by two nuts. The equipment is remotely controlled from a small unit which can be fixed under the dash-board of a car, and into which are plugged a 6 in. moving-coil loudspeaker and a moving-coil hand-microphone. The control unit has a 5-position switch for selecting the facilities required and a volume switch for the loudspeaker, and the microphone includes a press-to-talk switch which automatically switches the set from receive to transmit, or, for P.A. work, switches on the H.T. machine for the amplifier. All components and finishes are fully tropical, so that the equipment can be used in any part of the world.

Fig. 4. Complete equipment installed in back of Rover 14.

Receiver

This contains 11 valves, consisting of an R.F. amplifier and a mixer, each using a high-slope pentode controlled by a portion of the A.V.C., a crystal-controlled oscillator tripling in its anode circuit, a second tripler feeding the mixer, two variable-mu I.F. amplifiers with full A.V.C., a 3rd I.F amplifier operating with fixed bias, a double-diode detector and A.V.C. rectifier, a double-diode noise limiter, an A.F. amplifier using a variable-mu pentode controlled by A.V.C., and a beam-tetrode output stage. The signal/noise ratio is 10 db. at 1.5 μV and 20 db. at 5 μV input. The four I.F. transformers, which are tuned to 4.5 Mc/s., are designed to give a pass-band of approximately 60 Kc/s., firstly for use with multi-carrier systems,[8] and secondly for efficient operation of the noise limiter, the effectiveness of which depends on the ratio I.F. band-width/A.F. band-width: the response is — 40 db. at 100 Kc/s. off tune. The maximum audio power output is 3½ watts, and the A.V.C. becomes fully operative at an input between 1 and 2 μV, after which the output remains flat within about 3 db. up to an input of 100 mV. All stages employ British-made miniature valves except the output, which is a 6V6GT. The total consumption from the battery is under 6 amps. at 12 V.

Transmitter

This employs 6 valves in 4 stages: the crystal-controlled oscillator triples in its anode circuit and is followed by a second tripler, which supplies the driver stage, comprising two valves in parallel; these four valves are all miniature high-slope pentodes. The Class C power-amplifier stage uses two pentodes which deliver approximately 12 watts of R.F. power to the aerial. Anode modulation is used, the A.F. being supplied at low impedance from the amplifier unit and stepped up in the modulation transformer. Total battery consumption for the transmitter and amplifier is 2 amps. on stand-by and 11 amps. during transmission. A miniature relay, housed in the transmitter, switches the aerial to either the receiver or the transmitter.

Amplifier

The microphone transformer supplies two miniature high-slope pentodes in push-pull, which are R.C. coupled to two 6V6GT valves in push-pull; the output transformer low-impedance secondary delivers 10 watts to either the P.A. loudspeaker or the transmitter, switching being performed by a relay in the power unit. The battery current at 12 V for P.A. operation is 1 amp. on stand-by and 5 amps. during speech.

Power Unit

The standard model, for 12 V simplex operation, contains two rotary transformers to produce H.T. at 260 V: one supplies alternatively the receiver or the transmitter and the other the amplifier. This unit also contains hash and hum filters for the machines, and relays operated from the control unit which perform all the switching functions. Alternative models are available for 6 V and for duplex operation: the latter contains 3 machines, as the receiver remains on during transmission.

Results of Field Tests

After development, the equipment described was tested by the author in various districts, urban and rural, in England and Scotland, and also in the Oslo district in Norway. Most of these tests were made in a car, but others were in such diverse vehicles as a tram, a tug and a railway engine. During all of them, the equipment proved extremely reliable, although it was subjected to an abnormal amount of rough handling. Ranges of over 40 miles were obtained in a moving car on a number of occasions where the intervening country was comparatively flat, although 20 miles is a more usual range for consistent results when the country is moderately hilly and the fixed station is well sited. The range, of course, depends very much on the site of the fixed

(*Continued on page* 151.)

Velocity Modulation

Part I of a paper read before the Electronics Group of the Institute of Physics

By J. H. FREMLIN, Ph.D., F.Inst.P.*

IN this paper it is intended rather to give a general discussion of the various types of velocity-modulation tubes than to consider any one of them in very great detail. A great deal of work on several specialised types has been carried on during the war in a number of laboratories in this country and active preparations are being made for its publication. I do not wish to anticipate this work in any way, but it seems to me probable that a general paper may prove helpful to those who have not specialised in the field as an introduction to the subject.

The idea of velocity modulation arose at a time when people were much concerned with certain undesirable effects found in valves used at ultra-high frequencies. These effects were early regarded as being due to the finite transit time taken by electrons in their passage through the valve. This view was discussed, for example, by Benham[1] as early as 1928.

Many of the effects observed were due rather to lead inductances[2] than to transit time, but the papers on transit time were very useful in that they did show conclusively that it could lead to a considerable energy conversion between the high frequency field and the kinetic energies of the electrons.

* University of Birmingham.

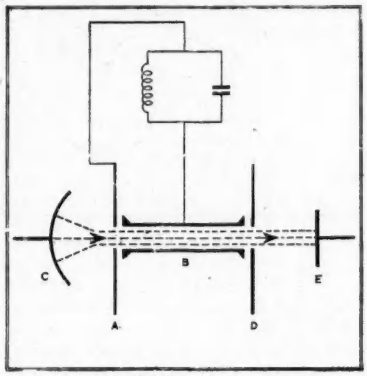


Fig. 1. Principle of the Heils' original oscillator.

This energy conversion experimentally showed itself as a rule as a damping of the high frequency field, although Llewellyn had shown how, in certain circumstances, the damping might become negative, *i.e.*, electrons might, on the average, lose kinetic energy to the profit of the high-frequency field.

Now the finite transit time can, of course, be minimised by the use of close electrode spacings and high current densities, but from its very nature cannot be eliminated.

In 1935 the basic paper on velocity modulation was published by A. and O. Heil[3], describing the principles of a patent taken out by them in February, 1934. They pointed out that, since we cannot avoid transit time, we ought to try to make use of it. They showed that a suitable variation of transit time could be used to obtain conversion from electron kinetic energy to high-frequency energy without any initial amplitude modulation of the current leaving the cathode. In this way the whole of the first-order grid loss power suffered by triode oscillators, for example, as a result of transit time, could be eliminated.

The system proposed by the Heils is shown in Fig. 1. A uniform electron beam is passed through the hole in the electrode A, then traverses B and D and is finally collected at E. All these electrodes may be at the same H.T. potential. A, D and E and the cathode C are all at R.F. earth potential. The electrode B is attached as indicated to an oscillatory circuit. Then when oscillation occurs the electron stream passing between A and B meets an alternately accelerating and decelerating field. The electron velocities, as they enter B, are therefore alternately greater and less than the original uniform values. Once they have entered B there is no further field acting on them, whatever happens to the instantaneous potential of B, as they are inside a kind of Faraday cage. Hence the velocity of each electron remains constant throughout its passage through B.

The variation of velocity with time is shown by the slope of the lines in Fig. 2, in which distance X from the

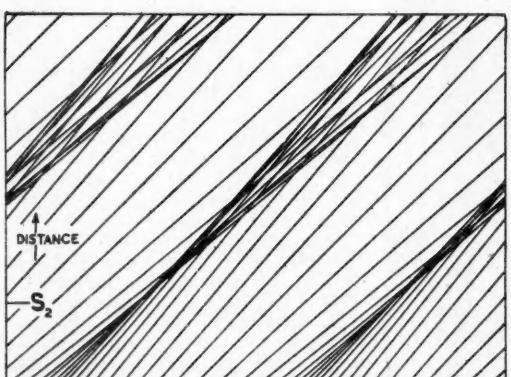


Fig. 2. Distance-time curves for electrons leaving the modulating gap at intervals of $\frac{1}{16}$ cycle. The modulating voltage amplitude is 0.3 V_0 where eV_0 is the initial electron energy.

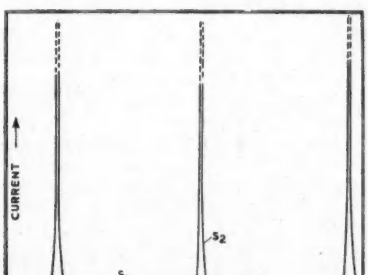


Fig. 3. Variation of current with time at the modulating gap (S_0) and at two points in the drift tube (S_1 and S_2).

gap AB is plotted against time of entry into B for a series of electrons reaching AB at intervals of 1/18 period over two periods of the high-frequency oscillation. It will be seen that electrons arriving at the gap AB during a retarding half cycle are slowed down as shown by the reduced slope of the corresponding trajectory lines in Fig. 2. The electrons passing AB in the following half-cycle are accelerated and will overhaul the previous set. This leads, as is clearly shown in the figure, to the building up of alternate bunches and rarefactions in the initially uniform electron beam, the current variation with time at the distances S_1, S_2 of Fig. 2 being shown in Fig. 3.

If the amplitude of oscillation of B is sufficiently great, then the current crossing the gap BD will have a large amplitude variation at the frequency of the high-frequency field. If the time taken to traverse B has a suitable value, the bunches will arrive to find the maximum retarding field between B and D and the combined kinetic energy which they lose will be far greater than the kinetic energy gained by the comparatively few electrons arriving half a cycle later to find an accelerating field.

Consequently, on balance, a considerable amount of energy is handed over to the high-frequency field each cycle. It will be noticed from Fig. 3 that the current wave-form is extremely rich in harmonic components. In passing, it may be mentioned that quite efficient v-m frequency multipliers can be made, giving up to ten times multiplication. The Heils calculated graphically the lengths of B and of the gap AB to get the best possible power transfer for several amplitudes of oscillation and showed that in the best condition some 35 per cent. of the D.C. energy of the electron beam could be converted into R.F. energy. For this, the time of flight of electrons between the centres of the two gaps was about $1\frac{1}{4}$ periods of the high-frequency field.

Several tubes were made by O. Heil intended to operate at wavelengths below 10 cm. at H.T. potentials of some thousands of volts so as to make the mechanical length of B large, even though $1\frac{1}{4}$ periods at this sort of wavelength is an extremely short time. None of these tubes, however, which mostly used circuits of the parallel-line type, showed any sign of oscillation.

The reason for this was as follows. It is not sufficient to calculate only the power gained from the electron beam for a given high-frequency voltage amplitude of B with respect to A and D. It is essential also to calculate the power which goes in ohmic losses in the circuit in maintaining this voltage. At centimetre wavelengths the skin depth is of the order of one or two ten-thousandths of an inch, so that ohmic losses are difficult to keep low and without complete shielding radiation losses are enormous.

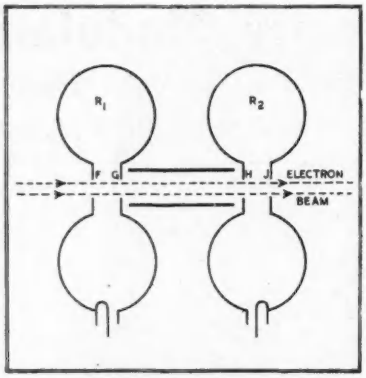
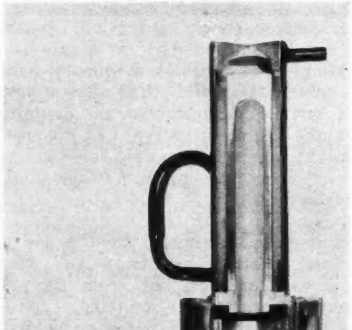


Fig. 4. Diagram of the Klystron.



Sectional view of modern Klystron
—By courtesy of the B.T.-H. Co.

The first real velocity-modulation tubes to operate satisfactorily were made quite independently by R. H. and S. F. Varian[4] at Stanford University, and it was only after their work had been published in 1939 that the practical possibilities of the system were generally realised. The great step forward which they made was in using hollow cavity circuits, which they called rhumbatrons, in which the losses were hundreds of times lower than had previously been tried, radiation losses in particular being entirely eliminated. Consequently the energy transferred from the beam exceeded that going in ohmic loss in the resonant circuits and sustained oscillation was possible with appreciable power available for a useful load. One of their early tubes, which they called klystrons, operating at 30 cm. wavelength, was capable of an output of several watts at an efficiency of about 5 per cent. The principle of their system is shown in Fig. 4. The modulating or buncher gap FG and the working or catcher gap HJ are now separated, which allows us a fresh degree of freedom in that the relative amplitudes in the two circuits may be varied by alteration of the coupling which feeds back power from the working to the modulating circuit. Using various simplifying assumptions Webster[5] calculated that the overall efficiency might rise as high as 58 per cent. if a very small modulating-gap amplitude and a very long drift-tube were used, when a larger working-gap amplitude is permissible without risk of reflecting electrons altogether. Unfortunately, it is not usually possible to maintain in practice the conditions corresponding to those assumptions so that an efficiency of 20 per cent. must even now be regarded as very good and it is doubtful whether much more than 25 per cent. has yet been achieved. Consequently, the theoretical advantage in efficiency over Heil's system is only apparent. There is, however, a practical advantage

that owing to the separation of circuits the system may be used as an amplifier.

In the middle of 1939 Heil proposed to combine the advantages of a single circuit with those of a completely enclosed cavity by using a modified section of coaxial-line, as shown in Fig. 5. Experimentally, systems of this type have given efficiencies closely approaching those of klystron oscillators.

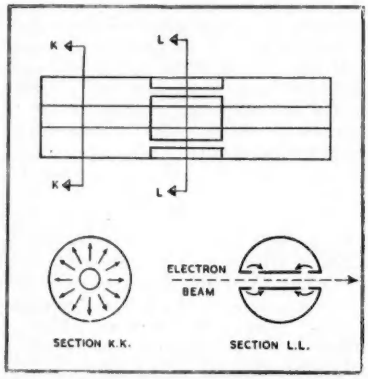


Fig. 5. Resonator of a coaxial-line oscillator. The arrows represent lines of electric force.

In Fig. 6 is shown an analogous system derived from a rectangular waveguide; the basic difference from the last is in the form of the electric field—indicated by arrows—and of current flow in the resonator walls, rather than in the rectangular shape.

Examination of the "rhumbatron" type of circuit used by the Varians introduces us to an interesting new phenomenon which often causes some perplexity on first acquaintance. This is the existence of an isolated electric field within each rhumbatron in spite of the fact that the whole of the exterior of each rhumbatron and the drift-tube itself are constantly at R.F. earth potential. The difficulty may perhaps best be understood by considering Fig. 7, in which the wall-thickness of a rhumbatron is exaggerated considerably and only a very small hole is left for the passage of the electron beam.

The instantaneous electric field distribution is indicated by the arrows. Then M and Q are both at earth potential as far as R.F. is concerned, and a field exists between N and P so that work is done on an electron travelling across NP (assuming that it crosses in a time short compared with the period of the R.F. field). At first sight, then, it would seem that N, P must be at different potentials so that a considerable potential difference must exist between M and N or between P and Q, which should also be able to do work on an electron. This is, however, a misapprehension due to the uncritical transference of ideas, gained from an understanding of static fields, to a system of non-static fields. Owing to the skin effect the field inside will not penetrate appreciably into the walls of the cavity, its amplitude distribution along the axis of the system being as shown in Fig. 8. From consideration of Fig. 8 it is clear that the work done between M and N on an electron will be negligible compared to that between N and P. In fact, in all high-frequency problems it is very desirable to concentrate attention on electric fields. The term "potential difference" should only be used with great caution. Even in the region between N and P we must be careful. An "instantaneous potential difference" V_1 between N and P may usefully be defined as the line integral of the field over NP, but the energy transfer to an electron will only be eV_1 when the electron goes across very fast; at all lower speeds it will be less. If a whole cycle, for instance, is taken, the energy transferred will be zero. so that for this electron the apparent potential difference is zero.

We now come to another phenomenon which, though it exists in ordinary valve oscillators, is of much greater importance in velocity-modulation oscillators, *i.e.*, that there is a definite minimum current below which oscillation cannot occur. We shall, for convenience, consider a system of the Heil or coaxial-line type.

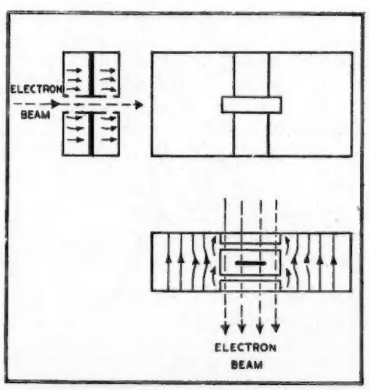


Fig. 6. Three views of a rectangular resonator. The arrows show the lines of electric force for a wave of H_{10} type.

Then let V_m be the amplitude of the instantaneous potential difference as defined above between B (of Fig. 1) and A or D. Then if R is the resonant shunt impedance between B and its surroundings, the power loss in the circuit will be $\frac{V_m^2}{2R}$.

Now the amount of the bunching of electrons that occurs depends upon the relative velocities of the electrons,

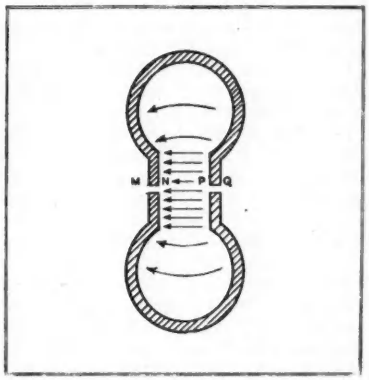


Fig. 7. Thick-walled rhumbatron. The arrows show the lines of electric force for the principal mode.

the proportional change in which will never be greater than $\sqrt{\frac{V_o \pm V_m}{V_o}}$ or $\frac{1}{\sqrt{V_o}}\sqrt{1 \pm \frac{V_m}{V_o}}$ when V_o is the D.C. potential of the system with respect to cathode which defines the velocity of entry of the electron stream. Then the bunching efficiency may be written as a polynomial in $\frac{V_m}{V_o}$ — and for small V_m we may say that the R.F. current amplitude at the second gap due to bunching will be proportional to $I_o \frac{V_m}{V_o}$ where I_o is the beam current.

Then the power transferred will be proportional to $I_o \frac{V_m}{V_o} \times V_m$, V_m being also the amplitude at the second gap. If we call the final constant of proportionality H, which may be regarded as the low-amplitude bunching efficiency, we have than that the power transferred from the beam to the field is $HI_o \frac{V_m^2}{V_o}$.

This will be greater than the losses if $HI_o \frac{V_m^2}{V_o} > \frac{V_m^2}{2R}$ or if $I_o > \frac{V_o}{2HR}$, which last relation is quite independent of V_m so long as the initial assumption is obeyed that it should be small compared with V_o.

Then for values of I_o below the critical value $I_s = \frac{V_o}{2HR}$ no oscillation can be maintained. For value of I_o above I_s more power will be transferred from the beam than is lost in the circuit. The difference will be stored in the field, *i.e.*, the amplitude of oscillation will increase. Owing to Johnson and shot noise there will always be a small fluctuating voltage amplitude in the circuit. For any current I_o greater than I_s this will build up until $\frac{V_m}{V_o}$ is no longer small, when over-bunching leads to a decreasing rate of build-up of power conversion. Thus at the critical current, there will be an extremely rapid change in oscillation amplitude from infinitesimal to finite and sometimes considerable; this current will be termed the starting current.

The starting power is often of more practical interest; this is I_sV_o and is proportional to V_o^2. Thus it is very desirable to use low voltages if tubes are desired to oscillate with a low power input; their high voltage was certainly an important factor in causing the non-oscillation of Heil's early tubes. When the starting current is of major importance this may justify the use of a permanent magnet for focusing the beam as this enables a high-density beam to be kept together at a much lower voltage than would be possible electrostatically.

The starting current is of the greatest importance at the shortest wavelengths. The reason for this is quite simple. Suppose we have a tube that has a starting current I_1 at a wavelength λ_1. Now suppose we reduce all its dimensions by a factor n, so that its operating wavelength is λ_1/n. Then, owing to the reduced skin depth the shunt impedance R_1 of the circuit will be reduced to $R_1/\sqrt{n}$ If the voltage remains the same the constant H remains the same and the starting current is hence increased by a factor $\sqrt{n}$. But the cross-sectional area of the cathode and of every part of the beam have been reduced by a factor n^2. Hence the starting current *density* has increased by a factor $n^{5/2}$.

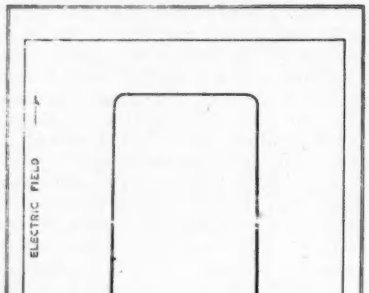


Fig. 8. Distribution of the electric field along the axis of the rhumbatron shown in Fig. 7.

At the shortest wavelengths, therefore, the starting current density becomes extremely high and the minimisation of starting current becomes the most important part of design.

To get a low starting current it is desirable, besides using a low voltage, to make H and R as large as possible. Making H large, for example, by using a very long drift-tube in which the electrons have plenty of time to bunch, has, however, a serious drawback. This is that before the amplitude of oscillation and hence the power transfer from the electron beam has risen very high, overbunching sets in, *i.e.*, the fast electrons in a bunch overshoot the slow and the bunch begins to spread out again. This point will be dealt with further below.

We are left with the problem of increasing the shunt impedance, which is simply that of reducing circuit losses. All that need be done in a general survey about this is to stress the fact that increasing R is not synonymous with increasing Q, a point which is often obscured by the frequent reference to the "high-Q circuits needed at high frequencies." The reason is easily seen by consideration of the half-wave coaxial-line circuit of Fig. 5. If, as will often be the case, the losses in this section are increased somewhat beyond the normal value by the glass of the vacuum envelope crossing the system at one point the Q would be increased by adding a similar system externally without such intrusion, making a whole-wavelength line. This is clear as the stored energy will be doubled, but the losses will not. On the other hand, the shunt impedance at the electron beam would be *decreased* as for the same voltage amplitude at the beam some more energy will be required to drive the extra length of line.

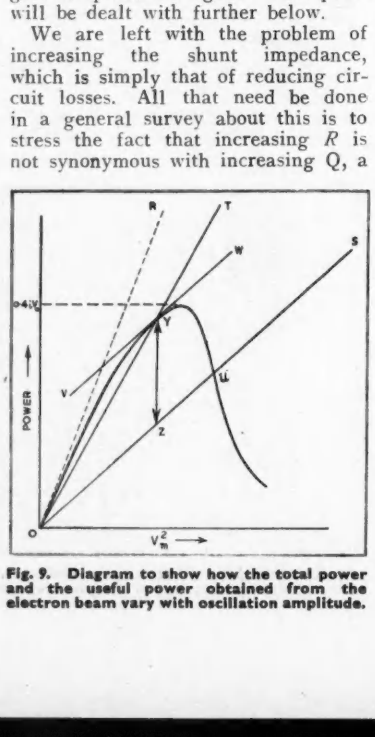


Fig. 9. Diagram to show how the total power and the useful power obtained from the electron beam vary with oscillation amplitude.

It may be felt that a long time has been spent in discussing whether or not oscillation will occur while final efficiency was dismissed very briefly. In considering now the possible useful power output, however, we shall see that this does depend very markedly on the value of the starting current, of which knowledge is therefore essential even if we are sure that it will be less than the total current we are prepared to use.

In Fig. 9 is sketched a curve showing the power conversion efficiency as a function of the square of the amplitude of oscillation V_m in the buncher of a typical klystron oscillator. As was shown earlier, for small amplitudes the power transfer is proportional to the square of the amplitude, so the curve starts off along the line OR. As V_m^2 increases overbunching begins to occur, at first reducing the rate of rise of efficiency and finally becoming so great as to *reduce* the power transfer. The falling part of the curve is usually incalculable beyond a certain point without a prohibitive amount of numerical work owing to the onset of total reflexion of some of the electrons, when the sideways deviations of the electrons, hitherto entirely neglected, become of first order importance. The maximum of the curve has been shown as occurring at 40 per cent. efficiency, which is as close to the 58 per cent. of an ideal klystron as is at all likely to be attainable in practice.

Now the power losses in linear circuits will always be proportional to V_m^2. Hence we may represent them as straight lines passing through the origin. Suppose that the line OS represents the power lost in the un-

loaded oscillator, *i.e.*, the ohmic loss in the resonators of the valve itself. Then in the absence of external load the amplitude will build up until the conditions represented by U, where OS crosses the curve, are reached. A little consideration will show that this represents a stable equilibrium. The efficiency of conversion of energy from the beam will usually be well below the maximum and the external efficiency is, of course, zero as no power is available for a useful load.

At a slightly lower amplitude than that represented by U, more power will be converted to R.F. from the beam kinetic energy than is absorbed by the resonators, the difference being represented at each value of V_m by the vertical height of the curve above the line OS. This difference will then clearly be a maximum for the value of V_m at which the tangent to the curve is parallel to the line OS. This tangent is drawn at VW, touching the curve at the point Y. The length of the vertical line YZ then represents the maximum power that can possibly be obtained from the device for any useful external load. In order to extract this maximum power it is only necessary to couple the load in just so tightly as to make the power-loss line lie along OT, cutting the curve at Y. It can be seen at once from the figure that the useful efficiency must always be less than the theoretical maximum efficiency of power conversion from the beam and that the reduction depends very markedly on the unloaded losses. If these are high, not only is the share of the power taken by the useful load reduced, but the total power developed is diminished.

An analytical treatment of the problem here discussed was worked out by Dr. C. J. Milner, at B.T.H., and is shortly to be published. The author is even more immediately indebted to Dr. Milner for a number of very useful suggestions which have been incorporated in the present paper.

Now the slopes of the lines OS, OT are simply $\frac{1}{2R_1}$, $\frac{1}{2R_2}$ where R_1, R_2 are the shunt impedances at the modulating gap for the unloaded and loaded conditions. The slopes are thus proportional to the unloaded and loaded starting currents, measurement of which can therefore be used to give a very reliable check on the operating condition of the tube. The constant of proportionality is, of course, obtainable if required from the fact that the slope of OR represents the circuit loss for which the starting current becomes equal to the running current.

It is hoped that the discussion of Fig. 9 has justified the importance which was attached to the minimisation of starting current which can now be seen to be directly related to the proportion of power which must inevitably be wasted. It is not proposed here to go into any detail as to how this minimisation can best be carried out. Extensive calculations on the subject have been carried out by the Electronics Group at S. T. & C., Ltd., for the publication of which arrangements have already been made. Here it is sufficient to say that the theory, of which a mere indication has been given, has been advanced quantitatively to a point where some of the types of tube so far described can be designed for a given performance with less uncertainty than is usually found in designing even an ordinary triode.

(*To be continued*)

Amplitude-Modulated Communication in the V.H.F. Band (*concluded from p. 146*).

station, and, in particular, on the height of its aerial, but even when this is quite poor, coverages of 10 miles can be obtained. The effect of intervening hills depends upon their contours and their proximity to the radio sets. For example, communication at 10 miles was maintained between a car and a 12-watt fixed station with a 1,000 ft. hill mid-way between them, but when the fixed station was sited on the side of a hill and the car was driven along a road cut in the opposite side of the hill, which rose steeply for several hundred feet above the road, the signals faded out at about 4 miles. In this case, when the car was driven up a side road to increase the distance by about a quarter of a mile and the height by perhaps 100 feet, signals again became clear.

On another occasion, a 12-watt fixed station was installed in a building on the quayside in Oslo, with its aerial about 80 ft. above water level, and the mobile set was fitted in a tug with a co-axial dipole aerial attached to the top of the mast. Very good results were obtained up to a range of 12 miles, although by then the propagation was almost entirely over high ground, and signals were still clearly readable when the vessel docked at this range in the shadow of a steep hill.

The noise limiter in the receiver proved extremely effective against impulsive interference, and, even in heavy traffic, very few cars caused any appreciable noise. Possibly the most severe test of the limiter was one made on a tram in Oslo. As there was insufficient clearance to the overhead wires for an aerial to be mounted on the roof, a dipole had to be fixed to the tram directly in front of the driver's compartment. The interference from the controller switchgear was the only type that was noticeable, and this appeared to punch very brief holes in the signal and was audible only as slight clicks; it did not cause the loss of any messages even when signals were only just readable due to bad screening by hills.

The effects of fading were completely absent until signal strength dropped to a level where background noise became appreciable, at which point fading could be detected by a flutter on the noise. The strength of the signal itself appeared perfectly steady so long as it remained above the level at which the A.V.C. started to operate.

The audio-frequency response, being restricted to cover only those frequencies necessary for good intelligibility, caused some loss of naturalness, but this was not sufficient to prevent recognition of the voices of different operators. However, it is not claimed that this equipment is suitable for purposes where high fidelity is essential, and there is no question that F.M. would be superior in such cases; but for use as a radio-telephone, it seems likely that in the majority of cases A.M. would prove just as satisfactory as F.M. and would offer the advantages of greater reliability and easier maintenance.

The author is indebted to Messrs. Pye, Ltd., for permission to publish this article and for the use of the photographs.

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A Modern Vibration Measurement Laboratory

By A. J. COGMAN*

Part 3. Types of Apparatus

(a) Apparatus for Measurement in the Low-Frequency Range

In the second part of this article it was explained that a resistance strain gauge responds to the application of mechanical strain by exhibiting a change of electrical resistance, the change being an increase for tensile strain and a decrease for compressive strain.

Thus the simplest form of apparatus for the measurement of strains of a steady nature is a Wheatstone Bridge. The Wheatstone Bridge is not normally used except in elementary strain gauge applications, however, its place usually being taken by a modified bridge circuit more specially designed to measure small increments or decrements of the gauge resistance.

A suitable circuit is shown in Fig. 17. The ratio arms R, R and the slide wire r are of accurately known resistance; the slide wire is chosen to have a linear change of resistance with angular rotation of its slider. It is calibrated, usually in terms of its fraction of R which is covered by angular rotation of its sliding contact. R_B is a finely adjustable variable resistance which is initially made equal to the unstrained resistance of the strain gauge, such that the galvanometer G shows no current flow. The slide wire is set at its zero position for this operation; if the zero position is designated as the centre point of the slide wire scale, measurements of tensile or compressive strain may be made at will.

Should the strain gauge respond to mechanical strain after the balancing adjustment has been made, the balance of the bridge circuit will become disturbed and the galvanometer will indicate a current flow. Adjustment of the sliding contact until zero current flow is again indicated will necessitate a movement of, say, y ohms change in the slide wire. The fractional resistance change in the strain gauge is then

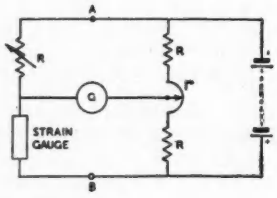


Fig. 17. A simple circuit for steady stress measuring. R.R. are the ratio arms of the bridge and r is a calibrated slide wire.

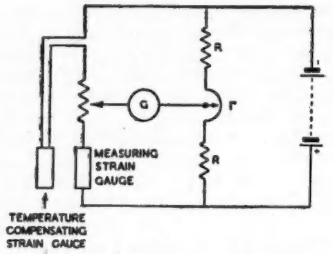


Fig. 18. The circuit of figure 17 modified to flow readings to be taken when temperature variation occurs at the point of application of the gauge. The arrangements for balancing are slightly different as may be seen.

$$\frac{\delta R}{R} = \frac{y}{2\,R + \frac{r}{2}}$$

This formula may be verified by reference to the diagram of Fig. 17.

More than one strain gauge may be used in conjunction with one slide wire and ratio-arm circuit, simply by wiring each gauge and adjustable resistance (R_B) circuit in parallel across the points A and B, the junction point of each pair being selected in turn by a selector switch connecting to the galvanometer.

This method of elaboration is employed as the basis of the 10-Circuit Strain Bridge shown in Fig. 6 (part 1 of this article).

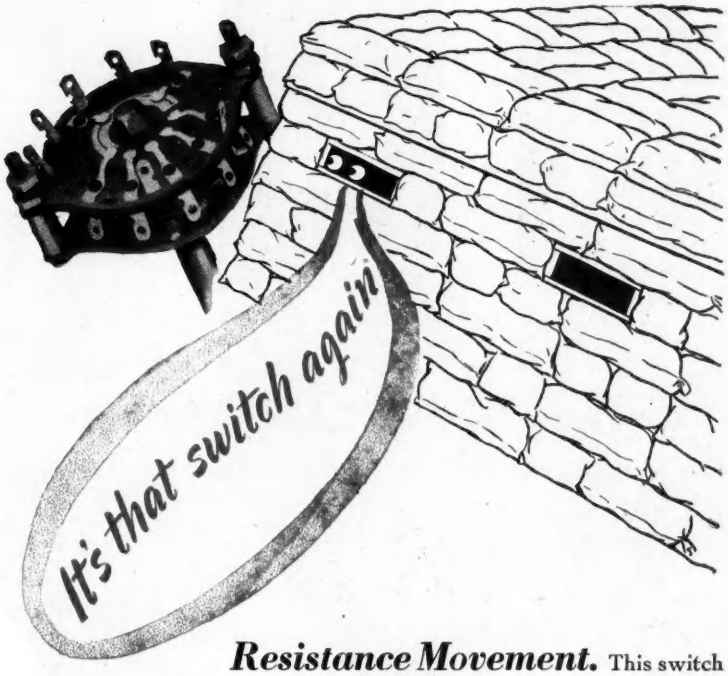
If it is desired to take measurements of slowly varying stress, or where measurements over protracted periods of time are required, it is generally necessary to compensate for changes of resistance in the strain gauge due to changes of temperature at its location, since such changes tend to mask those due to the strains which it is desired to measure. The circuit of Fig. 18 shows the basic arrangement for temperature compensation. The temperature compensating gauge is chosen to be as close as possible in characteristics to the measuring gauge; it is cemented to a small piece of the same material as that under test and placed as near as possible to the measuring gauge, but in such a manner that strains will not be set up in the piece. Temperature changes will now effect both gauges equally, since they should both have the same temperature equivalent stress (see part 2). Strain changes at the measuring gauge will therefore by the only influence causing the unbalance of the bridge circuit.

A small potential divider is introduced between the gauges to enable initial balance to be obtained; it is almost impossible to obtain two strain gauges of sufficiently equal resistance to give balance without this provision. If its resistance is not greater than 2 per cent. of the gauge resistance it will not cause errors of serious magnitude for most engineering purposes.

Operation of this circuit is otherwise similar to that of Fig. 17; the method suggested for the use of more than one gauge is equally applicable. Where manually operated apparatus is not easily usable, where permanent records for subsequent examination are required, or where it is necessary to measure stresses varying at less than 2 c/s. (120 c/min.) a method of operation shown in semi-schematic form in Fig. 19 has been developed.

This method avoids the use of a D.C.

* Late of Vibration Dept., de Havilland Propellers, Ltd.



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Filament Voltage ...	4.0 V.	Filament Voltage ...	2.5 V.	Filament Voltage ...	4.0 V.
Filament Current ...	7.0 A. approx.	Filament Current ...	5.0 A. approx.	Filament Current ...	2.7 A. approx.

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amplifier and may be extended to record a number of stress conditions simultaneously, dependent upon space available. As may be seen from Fig. 19, the strain gauge and temperature compensating gauge are formed into a bridge circuit whose remaining arms are formed by the centre-tapped winding of the transformer *T*. The bridge is fed with A.C. via the primary winding.

Balancing of the bridge is carried out as in Fig. 18, by a low resistance potential divider. The effect of strain at the gauge is to produce an alternating voltage across the attenuator and consequently a proportionate sine wave record is obtained with the oscillograph. The amplifier, cathode-ray tube and camera system shown may be designed to suit recording conditions; a galvanometer-type oscillograph may equally well be used where space permits, but a cathode-ray tube has still to be included for monitoring the signal.

In order that the amplifier and oscillograph may be calibrated when the apparatus is in use the switch S.W.I. is set to calibrate, when a voltage proportional to $\frac{R_1}{R_1+R_2} - \frac{1}{2}$ is applied to the amplifier input. R_1 and R_2 are chosen so that this applied voltage corresponds to that produced by a known fractional change of resistance in the strain gauge; thus, by comparison between the strain gauge records taken and the calibration records, the fractional change of strain gauge resistance occurring may be deduced.

The capacities (indicated by broken lines) connected across the strain gauge and compensator gauge may be required to obtain exact balance, should the shunt capacities across gauge and compensator differ appreciably.

This type of apparatus finds considerable use where steady strains of a slowly changing nature must be recorded; a record of aircraft undercarriage landing stresses is shown in Fig. 20; this is enlarged from the 16 mm. film used for recording purposes. In the apparatus in question the bridge feed is at 400 c/s. from a rotary transformer.

For displacement measurements in the low-frequency range the best type of instrument (as mentioned in part 2) is one recording mechanically.

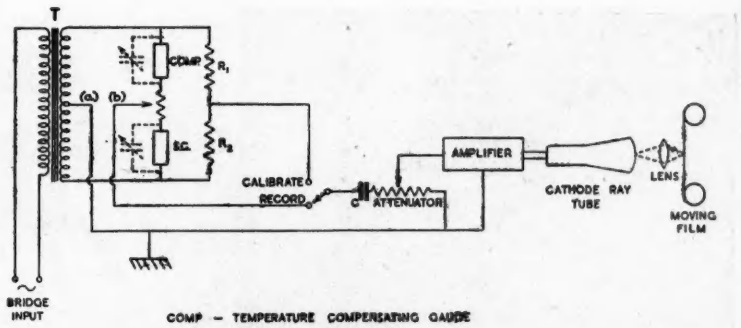


Fig. 19. A circuit for recording measurements of steady stress by means of an AC bridge circuit and normal AC. amplifier and oscillograph equipment. The use of a DC amplifier is avoided.

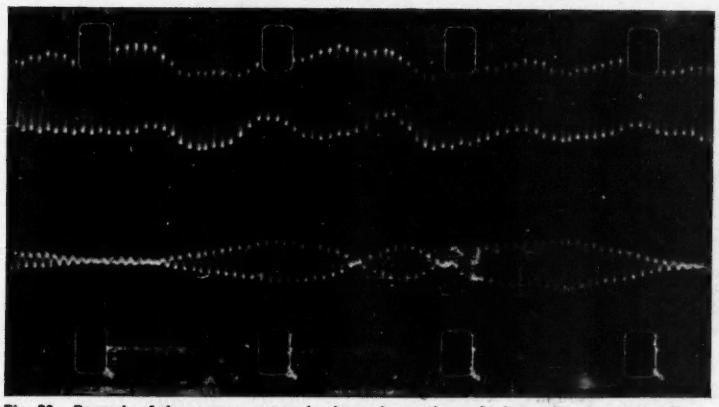


Fig. 20. Records of the stresses set up in the undercarriage of a heavy bomber on landing. The bridge operating frequency is 400 c/s.

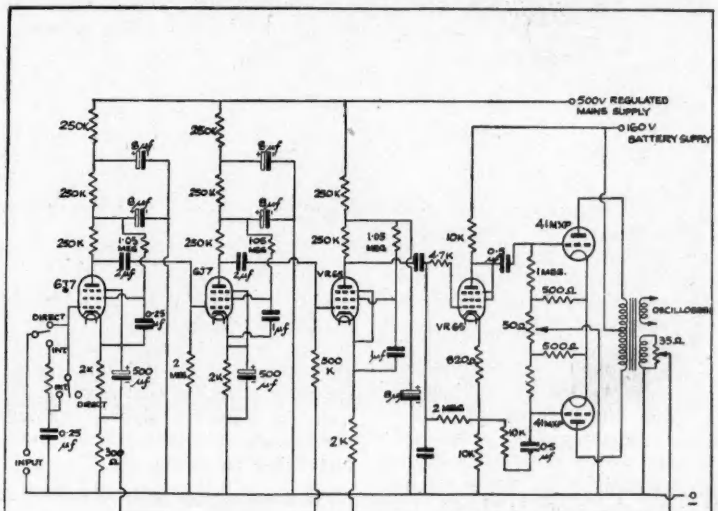


Fig. 21. Circuit diagram of stress-recording amplifier. The response is flat between 2 and 10,000 c/s and phase shift variation in this range is not greater than 10°.

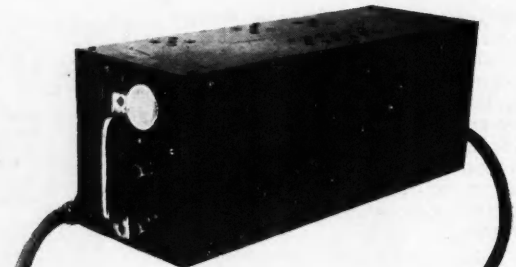


Fig. 22 (left). General view of stress-recording amplifier. The monitor cathode ray tube is in the top right hand corner, beneath it are the feedback and balance controls, the integrating circuit is introduced by the switch in the lower left corner.

Fig. 23 (right). Two-channel recording apparatus, used in conjunction with a small oscillograph camera for work where two simultaneous records are sufficient. It is connected to a small control panel by means of a multiple cable.

(b) Apparatus for use in the middle frequency range (2-1500 c/s)

(1) *The de Havilland Mobile Recording Unit.*

For large-scale testing of propeller and engine installations, a mobile recording unit has been developed by de Havilland Propellers, Ltd. This is capable of recording from strain gauges or vibration meters up to 16 simultaneous oscillograms. The method of recording is that shown diagrammatically in Fig. 7, part 1, and the various sections of the apparatus will be described here, necessarily rather concisely.

The input unit for each of the 16 amplifier channels has provision for recording from strain gauges of resistances from 100 to 25,000 ohms and also from vibration meters with or without an integrating stage. An attenuator giving progressive diminution of sensitivity in steps of 1/2, 1/4, 1/8, 1/16, etc., down to 1/1024 of the maximum is included for each channel, giving accurate control of gain. The amplifier circuit diagram is shown in Fig. 21.

The first two valves are 6J7 pentodes used as voltage amplifiers with negative feedback from the output of the second valve to the cathode circuit of the first. A VR65 voltage amplifier stage follows, after which comes a similar valve used as a phase inverter. The output valves are 41MXP triodes transformer coupled to the galvanometer winding in the oscillograph employed. A separate secondary winding for the negative feedback control is provided, feedback being returned to the cathode circuit of the first VR65. The double negative feedback circuit employed has been found desirable in the interests of stability. From the output valve anodes a monitor cathode-ray tube having a 1½-in. screen is fed with the amplifier signal, enabling the operator to examine the waveform when recording.

Amplifier phase shift variation is only 10° in the range from 2 c/s. – 10 Kc/s., and sensitivity is nearly constant over this same frequency range.

Stability of sensitivity is such that changes of less than 5 per cent. occur over long periods of operation.

Power supply is from a single-voltage regulated unit for the 500-volt H.T. supply and wet batteries feed the 160-volt supply. A time base circuit for the monitor tubes is also built as an external unit.

A general view of the amplifier is shown in Fig. 22.

The recording oscillograph used with this equipment will make 16 simultaneous records on 6 in. wide recording paper.

Galvanometer suspensions having a frequency range of 2 c/s. – 1,500 c/s. are employed, and timing sources for indicating 1/50 second intervals and engine revolution intervals on the records are incorporated.

These interval markers are rotary optical shutters operated by synchronous clock motors, one fed from the 50 c/s. mains and the other from the tachometer generator on the engine under test. A note on the operation of the integrating network is given in the appendix.

The complete apparatus is housed in a 3-ton van.

(2) *Two channel semi-portable equipment.*

When a large number of simultaneous oscillograms need not be recorded, and where space is limited, a scaled-down version of the mobile recording unit is available in the form shown in Fig. 23. Power supply is normally from 230-volt A.C. mains, but a rotary converter for battery operation is also available. Two recording channels are provided, with attenuators and optional integrating networks, the main characteristics being similar to those of the 16-channel mobile unit.

Records are taken on a two-channel oscillograph using 35 mm. perforated recording film.

(c) Apparatus for high frequency measurements

Only the initial work in this frequency range has yet been attempted, and much remains to be done. Measurements have been made successfully on gas turbines, both on stationary and rotating parts using strain gauges; vibration meters have also been used.

The standard amplifier used in the mobile recording unit has a satisfactory performance up to 10 Kc/s., and amplifiers having a higher frequency range are being developed; the oscillographs used for high-frequency recording (*see* Fig. 8, p. 70, of March issue) has cathode-ray tubes replacing the mirror-galvanometers used in the mid-frequency range. Film drive is by means of a ¼-H.P. motor which is run continuously at its rated speed, and coupled to the oscillograph by a magnetic clutch when a record is taken. By this means, rapid acceleration and deceleration of the film takes place, resulting in a minimum of waste.

Six 1½-in. cathode-ray tubes are used for recording purposes, and a reduced image of the six tubes is obtained on 59 mm. recording film by means of a large-aperture photographic lens.

Recording is possible at up to 10 ft. per second film speed, giving adequate definition of waveform at frequencies up to 6 Kc/s. and amplitude measurements above this frequency.

Perhaps one of the greatest problems of high-frequency work is the use of slip-rings on rotating parts at speeds of the order of 10,000 r.p.m. "Noise" is generally more severe than at lower speeds, and can only be eliminated by air cooling of the rings and keeping them extremely clean.

Another point of importance is that the self-capacity of screened cables, generally unimportant in the mid-frequency range, may affect frequency response, while also low-capacity switches and screened sections must be used for attenuator construction. A typical record taken on a gas tur-

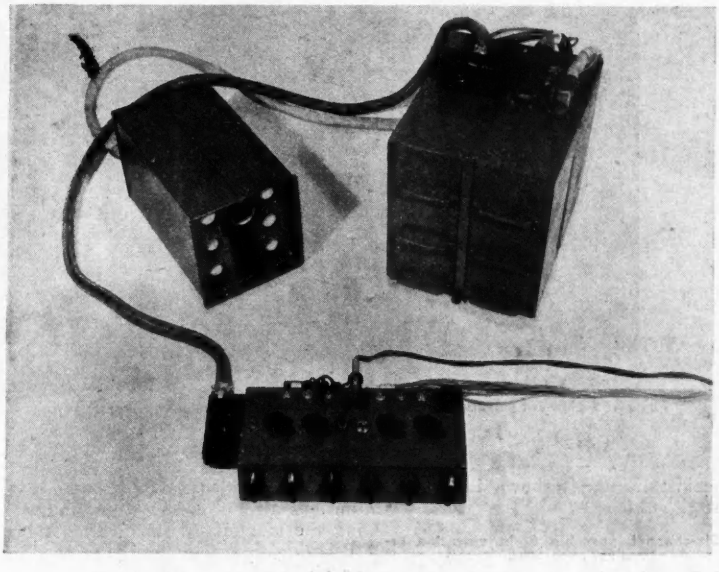


Fig. 24. 6-Channel portable and flight strain gauge recording apparatus. The units are as follows: Front, input unit; rear left, monitor unit; rear right, amplifier and power supply unit.

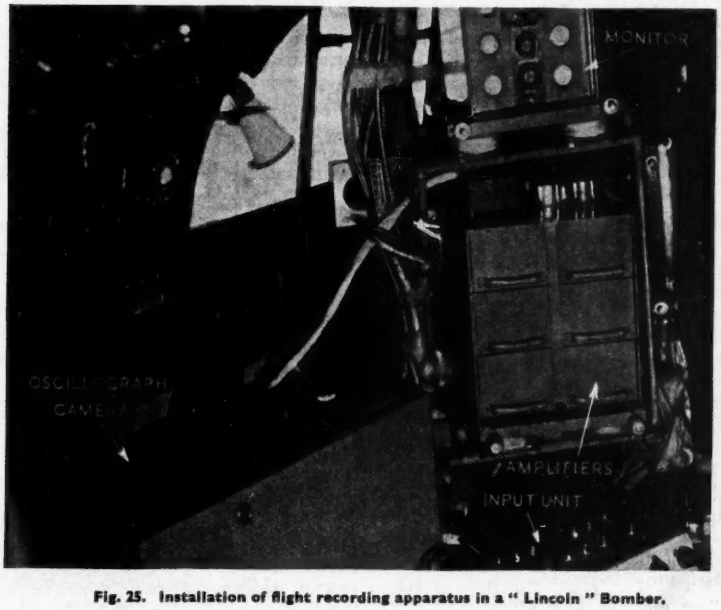


Fig. 25. Installation of flight recording apparatus in a "Lincoln" Bomber.

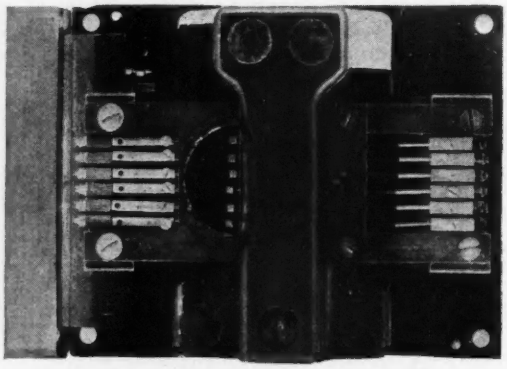


Fig. 26. 6-Element galvanometer, showing suspension and magnet system.

bine installation is shown in Fig. 9, part 1.

(d) Six-channel portable flight vibration recording apparatus.

It has often been necessary to make strain-gauge measurements in flight, and for such applications this 6-channel equipment is especially suitable.

The apparatus is shown in Fig. 24, excluding oscillograph. The three units are the input panel, amplifier and power pack unit and monitor unit.

The input unit will handle six strain gauges or vibration meters; it has the necessary integrating networks for the latter built in. Amplifier input attenuators are also provided.

The amplifier unit is built in the form of a miniature rack containing six amplifiers in drawer form; connexion of the amplifier input, output and supply voltages is made automatically on insertion of the amplifier in its compartment. The amplifiers are thus interchangeable, and a spare amplifier may be quickly inserted should a failure occur.

The amplifiers employ miniature valves and will deliver some 10 mW undistorted output; this is sufficient for the galvanometer suspensions used in the oscillograph to give a satisfactory indication.

The monitor unit employs R.C.A. type 913 miniature 1 in. cathode-ray tubes; an auxiliary amplifier (type 6J7 pentode) is incorporated in conjunction with each tube to provide a sufficient deflection of the tube spot from the recording amplifier output.

Pre-set controls for focus and brilliance are fitted to the monitor unit, as also is a film meter indicating the amount of film available for recording purposes in the oscillograph.

In the power supply unit a time-base circuit for providing the X-plate deflection of the monitor tubes is incorporated, together with an A.C. power supply unit for the amplifiers; A.C. operation is used since this allows normal ground operation when desired.

For portable and airborne work a small rotary transformer supplies the power unit, being itself operated by accumulators.

(e) Subsidiary apparatus

Six-element galvanometer unit.

See Fig. 26, This unit has been constructed for use in six and twelve element oscillographs now under development. It has a Ticonal Magnet assembly, giving an evenly distributed field for the six d'Arsonval type suspensions. Damping is provided by oil contained in holes in the metal block to the immediate left of the magnet poles. Vanes fitted to the suspensions at this position provide viscosity damping, the oil being retained solely by surface tension.

The semi-circular lens over the mirrors forms a part of the optical system, while a dust cover is normally fitted which totally encloses the instrument.

Appendix

Integration of the output of a velocity Vibration Meter.

The output of an electromagnetic velocity vibration meter is proportional to the relative velocity between the coil and magnetic flux, *i.e.*, to the velocity of the instrument in space.

Let e_o be the output voltage from the meter.

Thus $e_o = K \frac{ds}{dt}$ – (1) where K is a constant depending on the characteristics of the magnetic system,

and $\frac{ds}{dt}$ the velocity of movement.

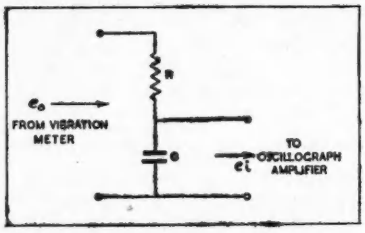


Fig. 27. The integrating circuit used for obtaining displacement measurements from an electromagnetic vibration meter. The function of the circuit is discussed in the appendix. The voltage e_o is the output from the vibration meter and e_i is the input to the recording apparatus.

Consider a condenser and resistance connected as shown in Fig. 27.

If R and C are such that e_1 (the input voltage to the recording equipment) is small in relation to e_o, and the current is i

$$\text{then } e_1 = \frac{1}{C}\int i\,dt$$

$$i \approx \frac{e_o}{R} \therefore e_1 = \frac{1}{C}\int \frac{e_o}{R}\,dt$$

$$\frac{de_1}{dt} = \frac{e_o}{CR}$$

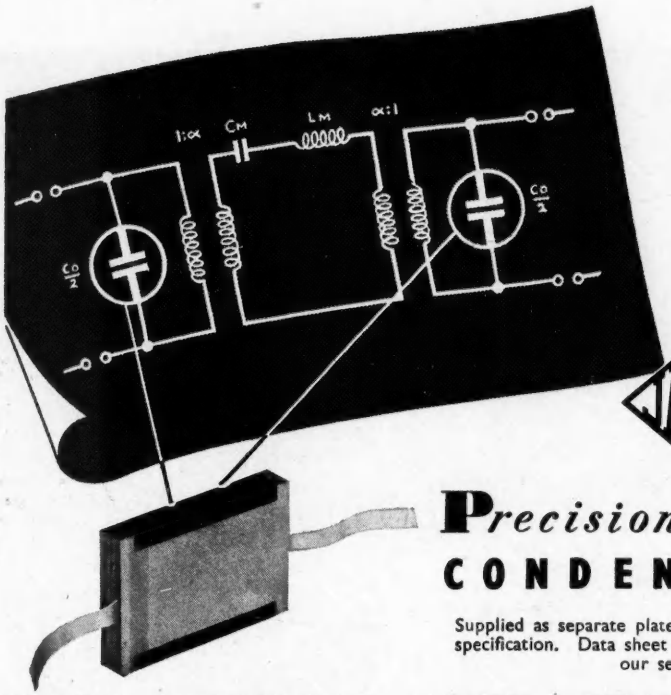
$$e_o = CR\frac{de_1}{dt} \quad \text{——(2)}$$

But $e_o = K\frac{ds}{dt}$ ((1) above)

..from (1) and (2) $K\frac{ds}{dt} = CR\left(\frac{de_1}{dt}\right)$

$$\therefore KS = CR\,e_1 \qquad e_1 = \frac{KS}{CR}$$

Thus the voltage e_1 applied to the amplifier input is proportional to the displacement of the vibration meter.



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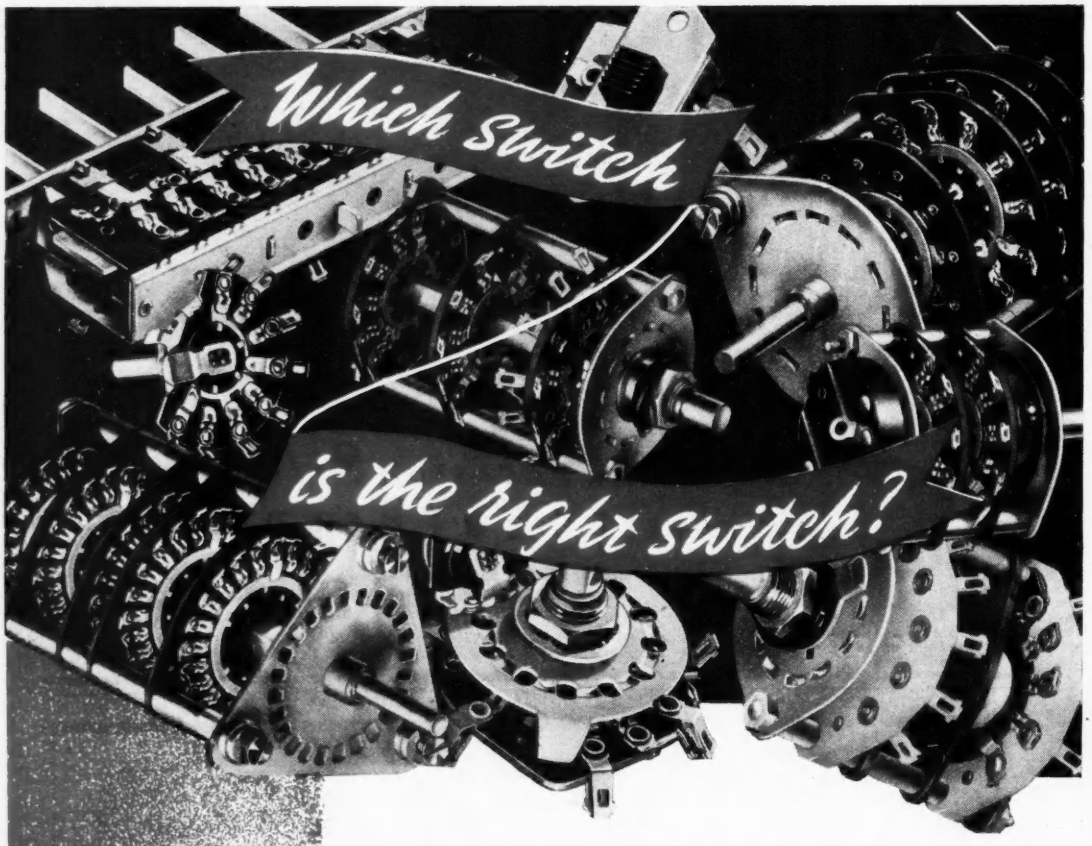

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28 Volts H.T. and L.T.?

By R. TERLECKI and J. W. WHITEHEAD, B.Sc., M.I.E.E.

Introduction

THROUGHOUT the past few years, tendencies in the design of communications receivers have been towards increases in weight, linear dimensions, power consumption, cost and maintenance. The resulting improvement in performance has been relatively small. For example, a communications receiver of to-day which, from a signal of one microvolt or less, modulated 30 per cent., produces an audio output 6 db. above the general noise level, may weigh anything between 60 and 80 lb. In the case of permanent ground installations, weight and physical dimensions produce few problems; but they are important factors when dealing with mobile or airborne installations. In the case of vehicular installations, a reduction in load is reflected in better vehicle performance coupled with longer vehicle life; and for aircraft, any reduction in weight and physical dimensions naturally gives greater freight-carrying ability and range.

Another disadvantage of large and complicated installations is that equipments of such a character intended for use under tropical conditions are most difficult to design and produce, whereas small and simple devices present few difficulties in this respect.

It is becoming increasingly fashionable to use 24- and 28-volt electrical supplies — particularly in the United States—and so in the design of airborne radio equipment it is natural to wonder whether it is a feasible proposition to develop receivers which operate directly from the 28-volt supply for their H.T. and L.T. voltages, without the usual intermediaries of rotary converters or vibrators. A study of the characteristics of readily obtainable valves, and suitable experiments, reveal that the scheme is a practicable one.

Design Details

Electrode Supply Voltages. — The nominal 28-volt accumulator develops terminal voltages on load which may vary between extremes of 22 and 32 volts, (depending on the degree of load and the age of the accumulator), corresponding to 28 volts + 14 per cent. and 28 volts − 21 per cent.; but in general the variation does not usually exceed ± 10 per cent. There would therefore appear to be a case for the development of valves with 14- and 28-volt heaters, and in fact the Sylvania Corporation have already begun to produce two such valves. In the meantime, there are no technical reasons—apart from possible wiring complications—against the use of 6.3- and 12.6-volt heater valves in suitable series-parallel arangements. Naturally, from the point of view of simplicity of wiring, the 12.6-volt series is to be preferred.

It should be noted that valves of very high slope do not function reliably on lowered heater voltages.

Screening Grids.—Apart from the particular—and unusual—case of using resistance-capacity couplings throughout the whole receiver, it is permissible, and even desirable, to connect all the screening grids to the common 28-volt positive line. If leads to the screening grids are kept reasonably short, there is no need for decoupling, with a consequent saving in components and cost.

Control Grids. — There are four methods by which bias voltages are obtained in receiving technique:

(i) Fixed bias obtained from a separate source or from a series resistance in the main negative lead of the H.T. circuit.

(ii) Automatic bias for each valve by separate cathode resistors.

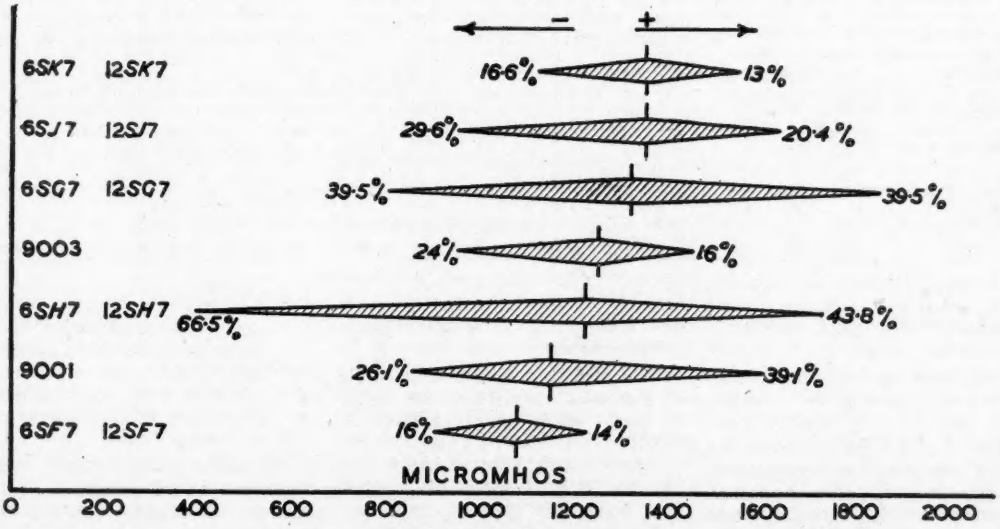


Fig. 1. Valve-to-valve variations in transconductance.

TABLE I

Type Number	Classification	Transconductance (μMHOS) at		Anode Current (mA) at Va=		Screen Current (mA) at Va=		Differential Anode Resistance (mΩ) at Va=		Cut-off Bias at*	Normal Bias at
		Va= 28 v.	Va= 250 v.	28 v.	250 v.	28v.	250 v.	28 v.	250 v.	Va =28 v.	Va =250 v.
6SK7-12SK7	Variable-mu pentode	1,350	2,000	2.0	9.2	0.6	2.4	>0.3	0.8	−10.0	− 3.0
6SJ7-12SJ7	R.F. Pentode ..	1,350	1,650	1.0	3.0	0.3	0.8	>0.75	>1.5	− 3.0	− 3.0
6SG7-12SG7	Semi variable-mu pentode	1,325	4,000	0.75	9.2	0.35	3.4	0.75	>1.0	− 5.0	− 2.5
9003	Variable-mu pentode	1,250	1,800	1.6	6.7	0.7	2.7	>0.3	0.7	−10.0	− 3.0
6SH7-12SH7	R.F. Pentode ..	1,200	4,900	0.35	10.8	0.15	4.1	>2.0	0.9	− 2.0	−10
9001	Pentode detector-amplifier	1,150	1,400	0.65	2.0	0.3	0.7	>0.7	>1.0	− 3.0	− 3.0
6SF7-12SF7	Diode-variable-mu pentode	1,075	2,050	2.0	12.4	0.6	3.3	>0.4	0.7	− 9.0	− 1.0

* Cut-off bias is that at transconductance 10 micromhos.

TABLE II

	R-C Coupled A.F. Amplifiers								Transformer or Choke Fed Amplifiers						
	6SJ7 and 12SJ7				6J5 and 12J5				6J5 and 12J5			6SR7 and 12SR7			
	Va=28v.		Va= 250 v.		Va= 28 v.		Va= 250 v.		Va= 28 v.		Va= 250 v.	Va=28 v.		Va =250v.	
Grid bias voltage ..	0	0	—	—	0	0	—	—	0	−1	−8	0	−1	−9	V.
Grid resistor	10	10	—	—	10	10	—	—	10	0	≤1.0	10	0		MΩ
Cathode resistor ..	0	0	500	1,530	0	0	1,020	6,950	0	0	—	0	0	—	Ω
Screen grid resistor ..	0.22	0.47	0.35	2.5	—	—	—	—	—	—	—	—	—	—	MΩ
Screen grid current ..	0.06	0.035	—	—	—	—	—	—	—	—	—	—	—	—	mA
Anode load resistor ..	0.1	0.22	0.1	0.5	0.05	0.22	0.05	0.25	—	—	—	—	—	—	MΩ
Anode resistance ..	—	—	—	—	—	—	—	—	12,250	14,500	7,700	15,750	18,000	8,500	Ω
Anode current	0.18	0.095	—	—	0.225	0.075	—	—	1.2	1.0	9.0	1.0	0.75	9.5	mA
Following grid resistor	0.22	1.0	0.1	2.0	0.1	1.0	0.05	1.0	—	—	—	—	—	—	MΩ
Transconductance ..	—	—	—	—	—	—	—	—	1,650	1,450	2,600	1,150	1,000	1,900	micro mhos.
Max. output (5% dist.)	4	4.5	72	89	2.5	4	41	64	—	—	—	—	—	—	V
Stage gain	34	47	67	263	11	13	14	14	20	21	20	18	18	16	V/V

(iii) Automatic bias from the second detector load resistor (*e.g.*, automatic gain control).

(iv) Bias developed by grid current in a resistor in the grid-to-filament circuit.

In conventional receiver design, the four methods are sometimes met separately, or more than one type may be used in a single stage; but in receivers using the 28-volt technique, method (iv) is the most successful. The individual merits and demerits are described below.

To deal with case (i) first, fixed bias of this type can always be readily obtained, but is ruled out because it provides no semi-automatic control to counteract the effect of any varying valve-to-valve characteristics which may be encountered.

Automatic bias developed by the plate current of valves in individual cathode resistors, although ideal at the more usual electrode voltages, is relatively valueless at very low anode potentials, because the required bias is then in the neighbourhood of the grid contact potential.

Automatic gain control regulated from the second detector is valuable for the handling of very strong signals, but with very low H.T. potentials

the inputs to the various stages are generally very small, and a grid-leak form of limiter will sometimes serve the same purpose.

Turning now to method (iv), we have here the most successful method by which initial grid bias can be obtained. It provides very uniform results with respect to widely varying valve-to-valve characteristics, is economical in components and, since all cathodes are grounded, the wiring is simplified. A suitable value of grid resistor in a resistance-capacity coupled amplifier is ten megohms, with two megohms for other types. Lower values result in higher standing grid currents, due to grid-circuit contact potentials, with correspondingly heavier damping of the various input circuits and resulting loss of gain.

Effect on Transconductance.—It is to be expected that high slope valves, such as the 6AC7, 6SH7 and 6SG7, will not, under conditions of low plate voltage, behave as well as valves of lower mutual conductance such as the 6K7 (Marconi-Osram KTW63), 6SK7 and 6SJ7. The former class develop relatively large grid-circuit contact potentials so that with grid-leak self-bias there is a tendency to over-bias with a consequent large reduction in gain. For example, the 6SH7, for which the normal grid-bias at a plate-to-filament potential difference of 250 volts is −1 volt, drops in transconductance from 4,900 to 1,200 micromhos when the "28-volt technique" is applied to it, (*see* Table I); but with the medium slope 6SJ7 the corresponding change in transconductance is only some 18 per cent. The American miniatures of the Type 9,000 group, which have been specially designed for V.H.F. working, show great promise under conditions of 28-volts H.T.

Effect of variations in characteristics from valve to valve.—It is important from the servicing point of view that the characteristics of any particular type of valve shall be approximately the same for all valves of the same type number, so that uniform receiver performance can be maintained when defective valves are exchanged for good ones.

In Fig. 1 we have the variations in transconductance for several types of valves which were examined at 28-volts H.T. in batches of 20 selected at random. It can be seen that the types which have the highest nominal transconductance exhibit the widest variations. To illustrate the case in point, the transconductance of the 6SH7 group varied from 66.5 per cent. below to 33.8 per cent. above the mean value of the 20 tested, whereas the variations encountered the valves of lower nominal slope are comparable with those which occur at plate potentials of 250 volts.

Valves

Variable-mu valves.—Variable-mu valves maintain good A.G.C. characteristics at low anode and screen potentials. The best examples are the 6SK7, 6K7 (Marconi-Osram KTW63) and 12SK7. Care has to be taken to prevent valves with high grid contact potentials from over-biasing the other stages by the insertion of isolating resistances for all the valves in the A.G.C. line. The A.G.C. feed is applied to the "earthy" end of the grid leak standing bias resistor

Frequency Changers. — Only one satisfactory mixer has been found. This is the 6SA7 or 12SA7.

Audio-frequency Amplifiers.—Table II enables comparison to be made between sundry audio-frequency amplifier valves under normal and "28-volt" conditions. Both inductive and resistance-capacity couplings are considered, and it can be seen that useful voltage gains are in every case obtainable.

The Output Stage.—There are two possibilities here, the type 2516 or better still, the Sylvania 28D7.

General Conclusions

The results obtained from experiments on the application of very low H.T. voltages to normal types of "international" valves reveal that a superheterodyne receiver with a single frequency band can be designed for communications or navigational purposes, with a sensitivity of the order of 5 microvolts or less for 100 milliwatts output, and a signal-to-noise ratio better than 6 db., in a container 3 in. by 3 in. by 4 in.

The elimination of high-voltage power units improves reliability and reduces weight, dimensions, maintenance and initial cost. Furthermore, facilities for production are improved by the relatively simple circuit diagram and the comparatively few components which are necessary. In addition, the small power dissipated permits the use of miniature components and condensers of low test voltage, with a further reduction in weight, cost and dimensions. Finally, the reduced dimensions of the equipment permit hermetic sealing of the container, thus giving an added improvement with respect to its use in extreme climatic conditions.

A rough re-design of a well-known American communications receiver for use on a 28-volt supply confirms many of the conclusions which have been drawn. The overall sensitivity of the modified receiver is only 6 db. down on the original figures for the unmodified receiver. The input power consumption is 1.2 amps. at 28 volts, compared with 125 watts when used on the normal 230-volt A.C. supply.

Electronically Controlled Model Train

Electronic engineers who are also model railway enthusiasts will be interested to learn that a train with full electronic control by means of radio signals is now available in the United States. The outfit comprises an "o" gauge, 6-8-6 steam locomotive, tender, four cars of different types, track, control equipment, etc., and has the following features: "Start," "stop" and "reverse train" electronically, whistle blown electronically, cars uncoupled electronically, and even unloaded electronically. All of these can take place anywhere on the track. Each unit of the train contains a miniature radio receiver and the control desk is, of course, a small transmitter.

Further details of the equipment can be obtained from the Lionel Corporation, 15th East 26th Street, New York 10, N.Y., U.S.A.

The "Electrotor"

A Small Low-Voltage Electric Motor of Novel Design

By J. V. EURICH *

THE field of application of small electric motors is rapidly widening, especially as a result of the ingenious mechanisms developed during the war. Among the more common uses of low-voltage motors are: Cine cameras and projectors, automatic razors, windscreen wipers, relay actuated movements in machines, and remote control devices. There is also a wide range of models and toys which require motive power operated from a battery.

With these in mind, the author and his brother, J. E. G. Eurich, have recently devised a motor capable of being operated from dry cells and built on completely unorthodox lines.

The construction is particularly simple and lends itself to mass production. There is no commutator, as generally accepted, and a complete absence of soldered joints. The field system is in the form of a ring permanent magnet, which can be made accurately to dimensions as small as 3/16 in. diameter by 3/16 in. long. A particularly interesting feature is the armature, which, as will be seen from the diagrams, can be wound in a continuous length and subsequently cut and bent into toroidal shape.

These motors,† to which the registered name "Electrotor" has been given, are at present made in three sizes:

(a) Type 001, possibly the smallest motor ever made, is 3/16 in. by 3/16 in. and weighs less than 1 gm. It runs at a speed of 7,000 r.p.m., from a 1½-volt cell and is used in special scientific instruments.

(b) Type 240 is the most popular size, 9/16 in. long by 7/8 in. diameter, weighing ¾ oz. and running at 5,000 r.p.m. from a 3-4½-volt battery.

(c) Type 440 is 1½ in. diameter by 1½ in. wide, and includes motors suitable for voltages from 6 to 24. These have been designed primarily for industrial use.

More powerful fractional horsepower motors are under development, and the range will be extended later to A.C./D.C. and synchronous motors.

* Managing Director, Rev Motors, Ltd., Bolton.
† Brit. Pat. 31596/46 and 34059/46.

Fig. 5. Photograph of the Type 200 Electrotor, approximately full size.

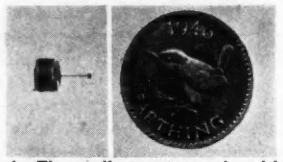


Fig. 4. The smallest motor made, with an overall diameter of ⅛ in. The farthing is shown full size for comparison.

Principle of Operation

As will be seen from the exploded view (Fig. 1), the Rev Electrotor consists essentially of:

A permanent ring magnet (e).
A gap-ring armature winding (f) mounted on a bobbin (i) and spindle (j).
Two end plates (b) with contacts (a).
Cover tape (c).
Two securing clips (d).

The edges of the winding (f) are bared and the contacts (a) bear directly upon these edges.

The winding (f) has a core of iron wires (g) of high permeability, cased in an insulating coat, upon which several layers of double nylon-covered copper wire (h) are wound in such a way that current flowing between the contacts energises all the layers.

Theory

Consider first the condition which

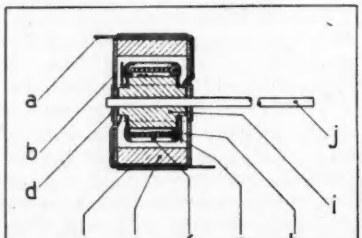


Fig. 3. Sectional drawing of the motion (see also Fig. 1)

obtains when no current is flowing, and the gap in the winding is adjacent to the S. pole of the permanent magnet (Fig. 2a). Both ends of the armature core have induced N. polarity and the peripheral centre of the core (which is adjacent to the N. pole of the magnet) has induced S. polarity.

When the current is applied (Fig. 2b) the winding becomes, in effect, a horse-shoe electro-magnet with polarity between the points of contact of the contacts and the ends of the core (but with concentrated polarity at its ends), the end nearest the + contact being a strengthened N. pole, and that nearest the − contact a S. pole of reduced strength. Consequently, the N. pole is attracted to, and the S. pole repelled by, the S. pole of the magnet, and rotation ensues, the effective torque depending upon the width of the gap.

It will be obvious that this width is vitally important, and considerable research has been devoted to the establishment of the exact dimensions necessary to give the required torque, consumption, and efficiency.

As rotation continues (Fig. 2c) the flux density of the N. pole of the winding loses its end concentration and becomes more evenly distributed between the end and the contact point, and eventually has concentration at the contact point; conversely, the flux density of the S. pole of the winding becomes progressively concentrated at the end of the core. There is, consequently, strong attraction to the poles of the magnet, with resulting high torque.

The next stage to be considered obtains when both ends of the gap are under the − contact (Fig. 2d) and have therefore strong S. polarity. The peripheral centre of the core (which is under the + contact) has similarly strong N. polarity. Rotation therefore continues.

The final stage occurs immediately after the gap has passed the −contact (Fig. 2e). The N. pole of the armature is now concentrated under the + contact, the terminal energised polarity being cancelled by the S. polarity induced by the magnet. Con-

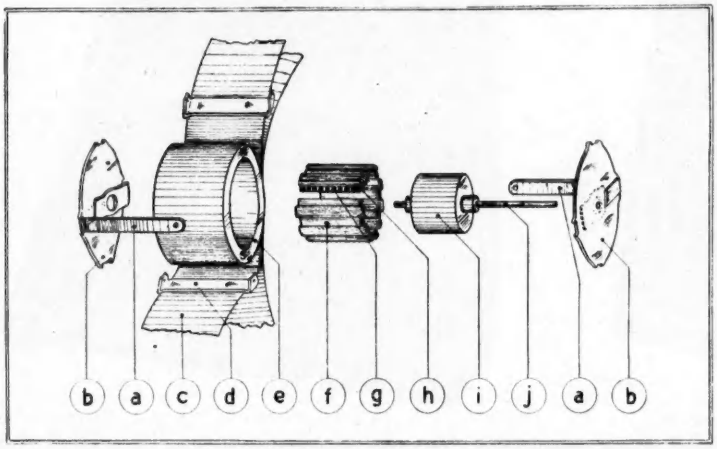


Fig. 1. Exploded view of motor: (a) Contact brushes fitted on insulating end plate. (b) End plates of insulating material. (c) Wrapping material securing brush tags to field cylinder. (d) Clamping strips for end plates. (e) Permanent magnet field cylinder. (f). Armature winding on iron wires. (g) laid side by side and curved to fit over the rotor moulding (i). (j) is the shaft.

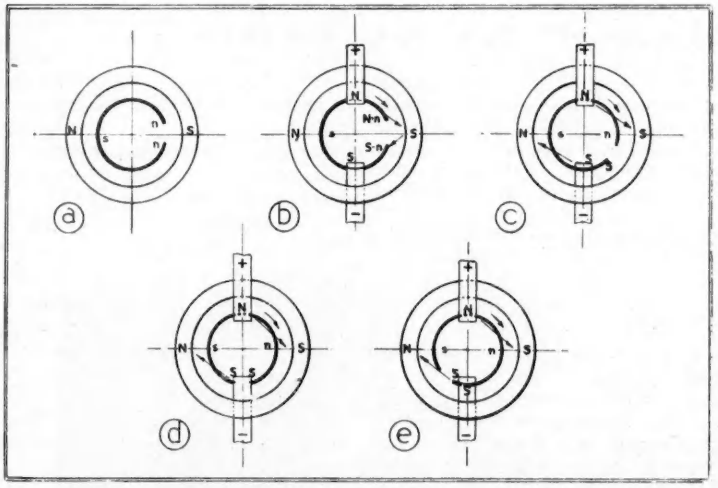


Fig. 2. Illustrating successive stages in the rotation of the armature. The capital letters, N, S, correspond to the permanent magnetism and the lower case letters, n, s, to the magnetism of the armature.

sequently, the point of flux concentration is attracted to the S. pole of the magnet. The following end of the armature (*i.e.*, that under the – contact) has strong S. polar concentration and is therefore strongly attracted to the N. pole of the magnet.

From this it will be seen that at two stages in the cycle, flux concentration at one or other of the ends of the winding is utilised to give an additional surge of power, and the whole cycle is balanced by the constant variation in the distribution of flux density.

The motors are being exhibited for the first time at the British Industrie Fair, and it is proposed to erect a large factory to cope with a mass-production of several million motors. The prices will depend on the quantities involved, and in bulk purchase it is anticipated that electrotors will prove to be the most economical power unit yet produced.

Nickel Plating on Steel by Chemical Reduction

Up to the present time, nickel coatings on steel have been obtained from aqueous solutions of nickel salts only by electrodeposition. A new process, however, developed by Abner Brenner and Grace E. Riddell, produces nickel deposits of good quality on steel without the use of an electric current.

The deposition is brought about by chemical reduction of a nickel salt with hypophosphite in a hot ammoniacal solution. The reaction is catalytic and under the prescribed conditions of concentration and $\not p$H, no reduction occurs in the solution unless certain metals, such as steel or nickel, are introduced into the bath. The reduction then occurs only at the surface of the immersed metal with the production of a coating of nickel of 96 to 97 per cent. purity.

One litre of a typical plating bath contains 30 grams of nickel chloride ($NiCl_2.6H_2O$); 10 grams of sodium hypophosphite; 50 grams of ammonium chloride; 100 grams of sodium citrate; and ammonium hydroxide to give a $\not p$H of 8 to 9. The bath is operated at a temperature of 90° C. About 0.00025 inch of nickel is deposited per hour, and thick deposits can be built up by long immersion. Since the hypophosphite is decomposed by the reaction, it must be replenished at intervals.

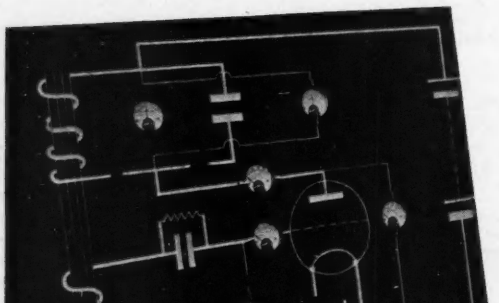
The chemical reduction method of plating nickel on steel is too expensive to displace electrodeposition of nickel because of the cost of the hypophosphite. However, it may find use in special applications, for example, plating small lots of steel parts which cannot be plated economically in a plating barrel. Since problems of current distribution are not involved in this process as in electroplating, it may be used for plating nickel in recesses that cannot be plated readily by electrodeposition.—*Tech. News Bulletin, U.S. Bureau of Standards.*

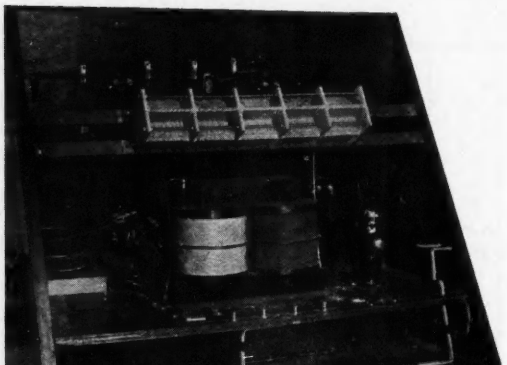
IT IS THE LAW

In Birmingham recently a large crowd gathered to watch the official testing of a neon display sign manufactured by Franco Signs Ltd.

As the law forbids a test of more than three minutes duration, police inspectors and Ministry of Fuel officials were present with stop-watches to time the try-out.

Advertisers Weekly, 6.3.47





Figs. 1 and 2. Front and rear View of Oscillator.

A Demonstration Valve Oscillator

By ERIC BRADSHAW, M.Sc.Tech., Ph.D., A.M.I.E.E.

STUDENTS often find difficulty in their first approach to the action of a valve oscillator. Ultra-low frequency oscillators, in which the cyclic current and voltage changes are sufficiently slow for them to be observed by moving-coil meters, are well known as a teaching aid in this connexion. Although the idea of "slowing-up" the oscillatory cycle is not new*, the author felt that details of such an oscillator might be of interest, in view of the help which it has apparently given to many students.

The circuit chosen for demonstration was that of the tuned-anode oscillator. The essential circuit was painted, in bold white lines on a black ground, on the front panel of the cabinet housing the oscillator components (Figs. 1 and 2 above). Details of the actual circuit, arranged for operation on 250-V D.C. mains, are shown in Fig. 3. Meters are provided to indicate grid-cathode voltage, anode-cathode voltage, voltage across the tuned circuit, grid current, anode current and the currents in the coil and condenser branches of the tuned circuit.

The meters are of normal construction, the movements having a resistance of 50-100 ohms per volt in every case except that of the grid-cathode voltmeter. The coil of this voltmeter was re-wound to give full-scale deflection with 200 μA. This modification was necessary to enable the effective resistance in parallel with C_2 to be kept sufficiently high to allow the oscillator to operate under "squegging" conditions.

The iron-cored coils used for L_1 and L_2 were chosen after a considerable number of trials of various available coils. L_1 and C_1 can be varied as shown, enabling the dependence of the oscillator frequency on the tuned circuit constants to be demonstrated. The maximum values of L_1 and C_2 result in an operating frequency of 2.3 cycles per second.

By increasing R_3 from 180 ohms to 6,000 ohms the following features of operation may be demonstrated:

(i) Change of mean grid voltage to a more negative value.

(ii) Reduction of grid current.

(iii) Transition from sinusoidal to "pulse" variation of the anode current, and reduction of the mean value of this current.

Increase of R_3 to successively greater values results in the oscillator squegging, with increasing relaxation times.

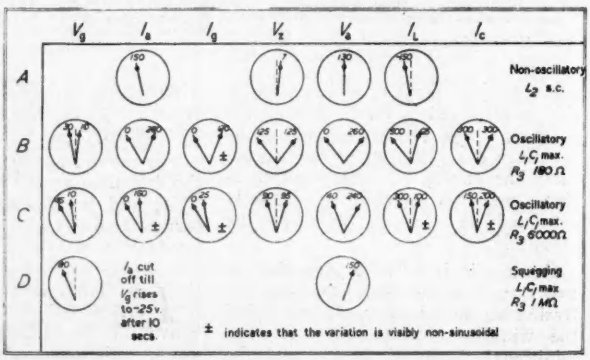


Fig. 4

* e.g. Admiralty Handbook of Wireless Telegraphy, Vol. II, Sect. K6.

Under the oscillatory regime, the fact that I_a, I_g and V_g are substantially in phase and V_a in anti-phase with V_g, can clearly be seen from inspection of the moving pointers of the meters. I_L and I_c can be seen to be approximately in quadrature with V_g, but the exact phase relationship cannot be gauged by eye.

The information contained in Fig. 4 was obtained by visual inspection of the meter pointers and shows:

at (a) the steady meter readings when the grid coil is short-circuited.

at (b) the limits of the pointer excursions in the case of an oscillatory regime, for R_3 = 180 ohms.

at (c) as for (b), but with R_3 = 6,000 ohms.

at (d) the almost steady meter readings at the beginning of a 10 sec. relaxation period, after the oscillator has executed a "squeg" with L_1 C_1 maximum and R_3 = 1 megohm.

In examining these values and relating them to each other, the moderate accuracy of the meters, the different amplitudes of pointer swing and the different motions of the pointers, due to the sinusoidal and non-sinusoidal quantities being measured, should be borne in mind as sources of faulty indications. The fact that the V_g indication is always negative, in Fig. 4(c), suggests that the re-winding of the meter coil has resulted in excessive damping of this meter.

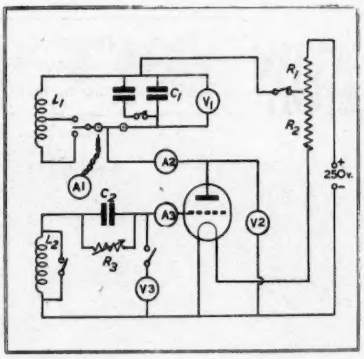
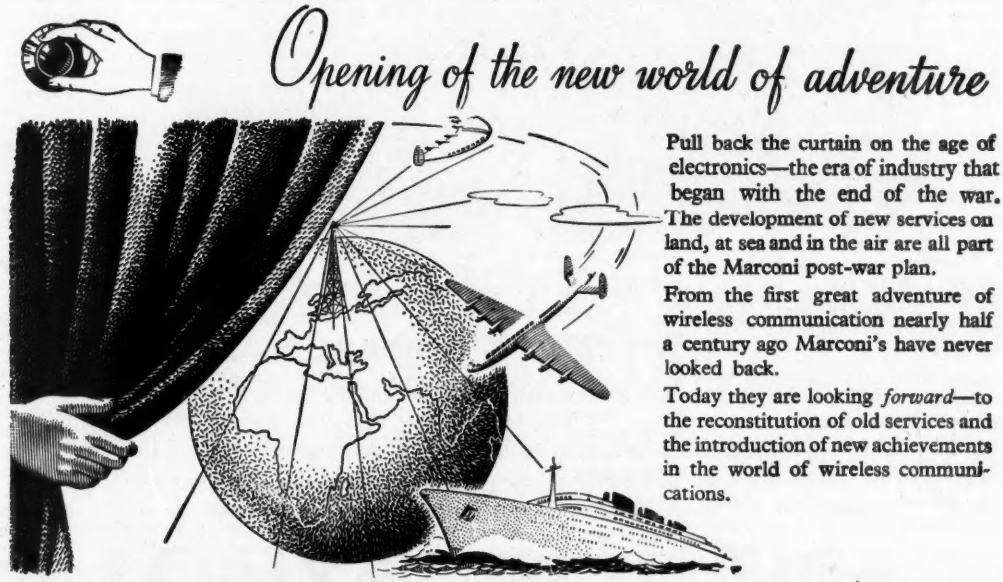


Fig. 3.

C_1 (total)		184 μF.
C_2		16 μF.
R_1 and R_2		250 ohms
R_3	180/1,160/6,000/20,000/500,000/1,000,000 ohms by switch.	
Meters	A1	1,250-0-1,250 mA.
	A2	0- 500 mA.
	A3	0- 200 mA.
	V_1	125-0-125 v.
	V_2	0-250 v.
	V_3	125-0-125 v.
Valve PX4.		

In relating the operation of such an oscillator to that of one working at a much higher frequency, there are, of course, several points which may be brought to the notice of the students. The differences are, however, those of degree rather than of principle, and are not such as to detract from the value of the demonstration. The differences may, in fact, be helpful in stressing certain features of operation at high frequency. The use of iron-cored coils with a high coupling coefficient and rather high losses is probably the most important difference. From Fig. 4(a) one can note the appreciable direct-voltage drop which occurs across L_1 under non-oscillatory conditions; Figs. 4(b) and 4(c) show the exaggerated ratio of anode current to circulating current and the non-sinusoidal nature of I_L and I_c. The absence of stray capacitances which are effective at the low operating frequency should also be borne in mind.

In conclusion, the author would like to thank his former colleagues in the Electrical Engineering Department of the Royal Technical College, Glasgow, engaged in the training of H.M. Forces, for their interest and help in the construction of the oscillator.


Opening of the new world of adventure
Pull back the curtain on the age of electronics—the era of industry that began with the end of the war. The development of new services on land, at sea and in the air are all part of the Marconi post-war plan.
From the first great adventure of wireless communication nearly half a century ago Marconi's have never looked back.
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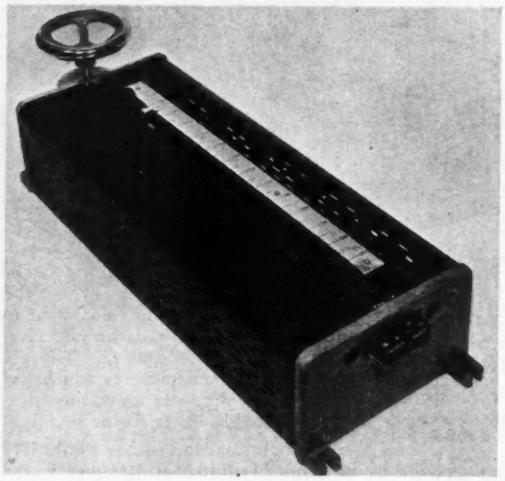
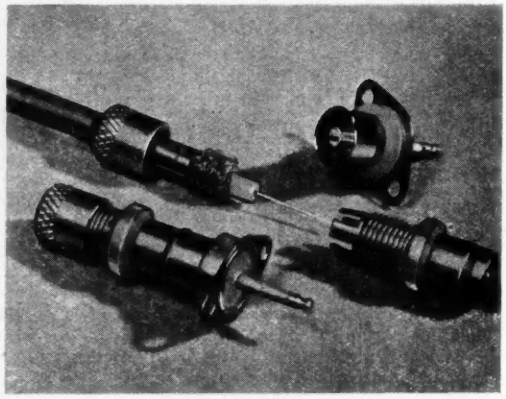
The R.C.M.F. Exhibition

A further selection of some of the radio and electronic components shown at the Radio Component Manufacturers' Exhibition held at the New Horticultural Hall on March 10–13.





Left : The Berco " Regavolt " Auto-transformer.

Above : New Co-axial plug and socket by Belling and Lee.

Cables

The Telegraph Construction and Maintenance Co., Ltd. displayed their well known range of " Telcon " radio frequency cables to which, since last year, has been added two Telcothene insulated transmission lines of the " Ribbon " type, one of 150 and the other of 300 ohms impedance.

They also exhibited for the first time " WYE " and " GEE " R.F. cables; the first is a range of double-screened flexible cables and the second a series of anti-microphonic cables which have been treated in a manner which largely eliminates the small spurious voltages associated with polythene insulated cables when subjected to flexing or impact. Another interesting co-axial cable had an impedance of 15 ohm.

Telegraph Construction and Maintenance Co., 22, Old Broad St. E.C.2.

Concentric cables with polythene dielectric are used in unbalanced circuits requiring stable electrical characteristics, and are suitable for use up to 1,000 Mc/s. On flexible screened twin cables a layer of metallised paper is lapped round the cable under the braid to eliminate contact resistance effects between the wires of the braiding.

Among the products shown by B.I. & Callenders Cables are waveguides, P.V.C. tubing, and polyethylene moulded connectors.

B.I. and Callenders Cables, Ltd., 72-78, Fleet Street, E.C.4.

Cathode Ray Tube Masks

In addition to rubber-to-metal bonded components, this company manufactures moulded rubber shapes in great variety, rubber viewing hoods for C.R. tubes, cut-out masks for framing television tubes, rubber grommets and other small parts.

Long and Hambly, Ltd., 51, Highgate Hill, N.19.

Ceramic Insulators

Over 23 types of metallised ceramic bushes for hermetic seals are available, many from stock. Catalogue No. 25 describes these, with full size outline drawings and photographs.

Recent work has resulted in the production of precision coil formers in a wide range with threads ground to an accuracy of 0.002 in. There is also a wide range of ceramic dielectric materials.

Steatite and Porcelain Products Ltd., Stourport-on-Severn, Glos.

Co-axial Plug and Socket

A new coaxial plug and socket (reference L.604 P & S) is designed for easy loading without special tools. It takes up to ¼ in. cable and the screen is gripped without soldering. The photograph shows one of a range of differing types of this component.

Belling and Lee, Ltd., Cambridge Arterial Road, Enfield, Middx.

WHEN WRITING TO ANY MANUFACTURER MENTIONED IN THIS REVIEW PLEASE MENTION " ELECTRONIC ENGINEERING " AS THE SOURCE OF INFORMATION.

Metal Chassis

Complete chassis in steel, brass, aluminium, or copper, finished bright cadmium, zinc, or nickel, or in cellulose. Prototype chassis or small quantities can be made to customers specification. This company particularly invite export business and can supply the chassis packed flat with suitable bending tool to ensure economical transportation.

All types of commercial presswork can be undertaken.

J. and H. Walter Ltd., Farm Lane, Fulham, S.W.6.

V.H.F. Signal Generator

This meets the demand for an instrument which will cover the range 10 to 300 Mc/s. It embodies many new features and is operated from A.C. supply or l.v. h.f. supplies.

Output continuously variable from 1 uV to 100 uV by means of a 5-step decade multiplier and calibrated dial.

Dimensions 12 × 14 × 7 in. Weight 36 lb.

Advance Components Ltd., Shernhall Street, Walthamstow, E.17.

Resistance Cord

An extremely flexible resistance cord wound on asbestos or glass fibre core and insulated with asbestos. Resistance 1 Ω per metre to 50,000 Ω per metre. Approximate weight 20 lb. per 1,000 yds. Suitable for line cords in A.C./D.C. receivers or for low temperature heating (below 400°C.).

Electrothermal Engineering Co., Ltd., 270, Neville Road, E.7.

YOU CAN'T STOP A MAN WITH A GOOD IDEA

"Sorry folk, but I must phone Lorival at once to see if rubber would do the job."

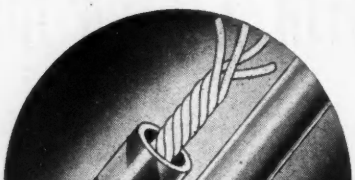
RUBBER OR PLASTICS?

★ *While each material possesses its own characteristics, in many applications one is as suitable as the other, and in these times of scarcity it is as well to have this in mind. Firms in need of components, complete articles or packaging should seek our advice, which is based upon wide experience and specialized knowledge. We produce articles in rubber and ebonite as well as plastics, and our service includes design and manufacture.*

U E L

LORIVAL PLASTICS

UNITED EBONITE AND LORIVAL LIMITED, LITTLE LEVER, NEAR BOLTON, LANCS



Operation Insulation

★ *A wide range of single colours, multiple colours and stripes enables the most complex codes to be employed.*

For the insulation of bare wires or the mechanical protection of insulated conductors, Delaflex offers three types in an extensive range of colours for circuit identification. Produced in Varnished Cotton, Varnished Rayon, and Rolled Silk in diameters from 0.5 mm. to conform to British Admiralty and Air Ministry specifications.

DELAFLEX
INSULATING SLEEVINGS

De La Rue
Insulation Limited
IMPERIAL HOUSE, REGENT STREET, LONDON, W.1.
ENGLAND
Telephone: REGent 2901. *Cables: Delinsul, London*
DA 12B/46

EVERY
MAN
FOR
HIMSELF . . .

Well, maybe we could adopt that policy of slapping Transformers together and churning them out as fast as possible irrespective of quality - you know, bash the next chap for all he is worth, let the future take care of itself.

But we think that attitude is wrong and in any case a Parmeko job always has been made up to a standard and not down to a price.

We realise that the success of our business depends upon the success of your business, if you go bust then we go bust because you don't buy any more Transformers. In any case when a new customer comes to us we like to feel that in 20 years time we shall still be making some very good Transformers for him . . .

PARMEKO OF LEICESTER.
MAKERS OF TRANSFORMERS.

High Intensity Lamps

A series of high intensity lamps was shown by Dawe Instruments for high speed photography. These cover studio requirements with an energy of 450 joules, and a flash duration of 100 microseconds, press work with a portable model having a similar duration and energy of 100 joules, and projectile or high speed machinery photography with a special model having a duration of about 1 or 2 microseconds. To indicate the high effective intensity the makers claim that the three equipments can be used for full length pictures with normal high speed films at lens apertures of F 32, F 11 and F 4.5 respectively.

Dawe Instruments, Ltd.,
Harlequin Avenue, Gt. West Road,
Brentford, Middx.

High Resistance Wire-wound Potentiometers

Accurately wound high resistance potentiometers are available in a wide variety of characteristics—linear, tapered, log. law, or non-inductive. The rating is 20 W max. in the linear law and 15 W in the graded types.

In linear law a resistance range from 10 to 500,000 ohm can be supplied, and it is claimed that this is the only wire-wound precision potentiometer manufactured with such a high maximum resistance.

Reliance Manufacturing Co.,
Sutherland Road,
Walthamstow, E.17.

Stud Switches

A new range of rotary stud selector switches of specially robust design with self contained click action supplied with both shorting and non-shorting contacts was shown. These will be particularly useful for selecting tappings on small transformers and their very low contact resistance also makes them suitable for ammeter and voltmeter switching applications.

British Electrical Resistance Co.,
329, *High Holborn, W.C.*1.

Stud switches of instrument quality made in a range of three sizes, each available with different arrangements of contacts. A feature is the provision of an insulated fanning disk to steady the wiring on the studs and prevent fracture of the joints due to any cable movement. Beryllium contact brushes and studs are available on the new range which is now available.

This company also manufactures faders, attenuators, both fixed and variable, vitreous wire-wound resistors, continuously variable potentiometers, miniature wire-wound resistors, etc.

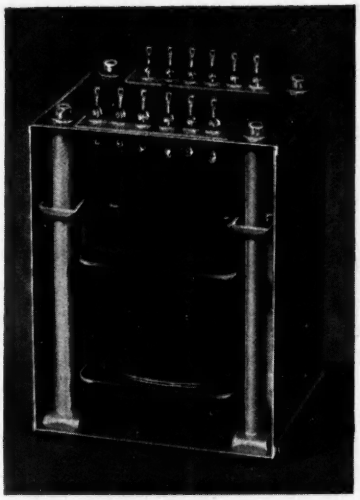
Painton and Co.,
Kingsthorpe, Northampton.

12-in. P.M. Loudspeaker

A medium heavy duty reproducer, the frequency response of which is ideal for small cinemas, public address installations, high power radiograms etc., is made by Messrs. Goodmans Industries, Ltd. Rugged precision construction throughout ensures a high degree of reliability under all conditions. Some points are:—

Fundamental response 75 c.p.s., voice coil impedance 15 ohm at 400 c/s., Maximum power capacity 12 watt peak A.C. input on flat 4 in. baffle, 15 watt horn loaded. Nett weight 11 lbs. 4 ozs. (No transformer is fitted).

Messrs. Goodmans Industries, Ltd.,
Wembley, Middx.

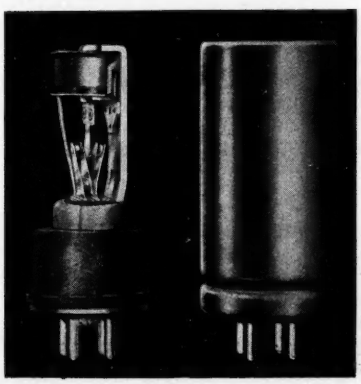


Sealed transformer by Associated Electronic Engineers (col. iii)

The "Hushatone" Reproducer

The "Hushatone" is a high-quality reproducer designed to replace the loudspeaker or headphones and is intended to be placed under a pillow or cushion to provide individual personal listening to radio programmes, etc., without causing disturbance or annoyance to others in the near vicinity. Hermetically sealed, it can be dipped into disinfecting solutions with temperatures not exceeding 120°F.

Cosmocord Limited,
Enfield, Middx.



Vibrator by Wimbledon Engineering (col. iii)

Transformers

On the Associated Electronic Engineers' stand could be seen a number of examples of modern technique in hermetic sealing as applied to transformers. The BNN audio range, employing single, dual or tri-alloy screening has now been developed with a multiple metal/glass seal base. An exploded view shows that a tubular structure is provided in the can and that the fixings form part of this structure. The purpose of this is to ensure that the transformer is held by its core structure and no strain is placed on the can.

Associated Electronic Engineers Ltd.,
10, *Dalston Gardens,*
Stanmore, Middx.

New Auto-Transformer

The new Berco "Regavolt" auto-transformer is a useful source of supply at any voltage from zero to 300 V from 230 V mains, and is designed for use in laboratories, test rooms, photographic studios, and similar applications. It can also be used as a mains voltage stabiliser to maintain constant supply voltage, either by hand or with automatic operation.

British Electrical Resistance Co.,
329, *High Holborn, W.C.*1.

Valveholders

"Clix" valveholders for the new British bases B9G and B7G in silica-loaded polystyrene and ceramic. These permit the soldering to the tag without the use of a jig, as the tag is independent of the movement of the socket. These holders have the added advantage of a uniform diameter above and below the fixing saddle, achieved by an improved method of fixing the saddle to the body.

British Mechanical Productions, Ltd.,
1, *Church Road, Leatherhead, Surrey.*

Manufactured under "Amphenol" licence, the McMurdo Instrument Co. have produced a full range of chassis mounting valveholders in bakelite and ceramic, both for British and American valve types.

McMurdo Instrument Co., Ltd.,
Victoria Works,
Ashtead, Surrey.

Vibrators

Both synchronous and non-synchronous types are manufactured in tropical-finished metal cases, fitted with U.X. bases.

The following is a typical specification:
D.C. input 6 V (15 per cent. working).
Starting voltage 4 V.
Coil current 170 mA.
Input current (max.) 5 A.
Nominal rating 30 W.
Size 1½ in. d. by 3¼ in. long.

Vibrators can be supplied to special order for input voltages from 1.5 to 250 V D.C.

Wimbledon Engineering Co. Ltd.,
Lower Morden, Surrey.

NOTES FROM THE INDUSTRY

Sir Stanley Angwin, D.S.O., M.C.

It is announced from the Department of Scientific and Industrial Research that Sir Stanley Angwin has been appointed chairman of the Radio Research Board in succession to Lieut.-Colonel Sir George Lee, O.B.E., M.C. Sir Stanley is chairman of Cable and Wireless, Ltd. He was engineer-in-chief of the G.P.O. and is a past-president of the Institution of Electrical Engineers.

Permanent Director of S.I.M.A.

Mr. A. J. Philpot, C.B.E., M.A., B.Sc., F.Inst.P., has been appointed director of the Scientific Instrument Manufacturers' Association of Great Britain, Ltd. Mr. Philpot is director of the British Scientific Instrument Research Association which is the oldest research association in the country.

Radio Communication and Electronic Engineering Association

The Council of the Radio Communication and Electronic Engineering Association have re-elected Mr. C. O. Stanley, C.B.E. (Pye, Ltd.) as chairman of the Association for 1947, and Mr. L. T. Hinton, B.Sc. (Standard Telephones and Cables, Ltd.), has been elected vice-chairman.

Recent new members of the Association are Messrs. W. E. Knorr and Co., Ltd., the Sperry Gyroscope Co., Ltd., the Marconi International Marine Communication Co., and the International Marine Radio Co., Ltd.

British Agent for Hufford Machine Works, Inc.

A. C. Wickman, Ltd., Coventry, announce that they have been appointed sole agents in this country, the British Empire and Europe (excluding Russia) for "Hufford" hydraulic stretch-forming machines, designed and manufactured by Hufford Works, Inc., California.

Taylor Electrical Instruments, Ltd., Revised Prices

Taylor Electrical Instruments, Ltd., announce the following revisions in prices of their meters:

Model 120A Taylor Junior, from £8 10s. to £7 10s.

Model 85A/P Universal Meter, from £21 to £19 19s.

Model 110B A.C. Measuring Bridge, from £14 14s. to £12 12s.

Model 45A/P Valve Tester from £20 to £21.

Model 47A/P Valve Tester and Universal Meter from £25 to £26.

Scientific Instruments at the B.I.F.

The Scientific Instruments Section of the 1947 British Industries Fair will be a composite stand covering almost 14,500 sq. ft. in which 86 firms, under the aegis of the Scientific Instrument Manufacturers' Association of Great Britain, Ltd., will display scientific instruments of almost every possible kind.

Service Valve Equivalents

The Radio Society of Great Britain has prepared a guide to Service Valve Equivalents for valves below 150 W dissipation. Continental valves are also included and there is a section on U.S. Signal Corps valves. Copies can be obtained, price 9d., from the R.S.G.B. at New Ruskin House, Little Russell Street, W.C.1., or from Webbs Radio, 14 Soho Street, London, W.1.

A Precision Standard Signal Generator

Messrs. Airmec, Ltd., of Wadsworth Road, Perivale, announce the production of a standard signal generator which complies with the R.M.A. Specification and possesses exceptional inherent stability and extreme accuracy.

Outstanding features claimed are:

Carrier frequency 80 Kc/s.-25 Mc/s.

Five ranges covered by 3 scales on main dial.

Incremental tuning at all frequencies.

Output continuously variable from 1 μV.-$10^5\mu$V.

Sine wave modulation up to 80 per cent. at 400 c/s.

Radiation less than 0.25 μV. at 25 Mc/s. with or without case.

A descriptive leaflet can be obtained from the manufacturers at the address given. This instrument is the forerunner of a complete range of electronic instruments to be produced by this company.

Kodak Applied Photography Exhibition

Kodak have prepared an Exhibition of Applied Photography which aims to show how photography is being used to solve problems in industry, in scientific research and in the recording and communication of information. Among the subjects dealt with are: high-speed photography in analysis motion, stereoscopic photography, industrial radiography, photo-lofting (transfer-sensitising), photo-elastic stress analysis, the application of document copying to industry and commerce and quality control by photo-micrography, and other photographic methods.

The Exhibition is being held at Australia House, Strand, London, W.C., from May 7 to May 16, and will be open each day from 10 a.m. to 5.30 p.m. Saturday and Sunday excluded. Admission is by invitation cards, obtainable from the Industrial Sales Department, Kodak Limited, Wealdstone, Harrow, Middlesex.

The Design and Production of X-ray Tubes for Crystallographic Purposes

The X-ray Analysis Group of the Institute of Physics has recently established an X-ray Tube Panel under the chairmanship of Dr. A. Taylor, F.I.M., F.Inst.P. The Panel will review existing and projected X-ray tubes and X-ray tube production in this country, and where supply or quality is not satisfactory, specifications will be prepared for the type of tube concerned and production or improvement will be encouraged by appropriate means.

Anyone interested in X-ray tubes for crystallographic purposes who is not a member of the X-ray Analysis Group and who wishes to ensure that his views and requirements are considered is invited to communicate with the Honorary Secretary of the Panel, Mr. J. N. Kellar, A.Inst.P., Crystallographic Laboratory, Cavendish Laboratory, Cambridge.

Frequency Modulated Broadcasting

It is announced that Marconi's Wireless Telegraph Co., Ltd., are to supply a 25-kilowatt frequency modulated broadcasting transmitter to the B.B.C. This will be the first frequency modulated transmitter to be put into regular service by the B.B.C. and will embody some notable improvements in the art.

Literature Received

Electro Plating Equipment (Runbaken Electrical Products).

Brush D.C. Amplifier (Brush Development Co., U.S.A.).

Data on New Thermionic Tubes (Park Royal Scientific Instruments, Ltd.).

"Radyne" Radio Heaters (Radio Heaters).

"Duritas" Carbide Dies (William Jessop & Sons, Ltd.).

MAY MEETINGS

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Radio Section

Date: May 7. Time: 5.30 p.m.
Lecture: "Accurate Measurement of the Group Velocity of Radio Waves in the Atmosphere, using Radar Technique."
By: R. A. Smith, M.A., Ph.D., E. Franklin, B.Sc., Ph.D., and F. B. Whiting, B.Sc.

Date: May 13 Time: 5.30 p.m.
Discussion on: "Future Trend of Component Design for the Services."
Opened by: G. W. Sutton, Ph.D., B.Sc., and E. M. Lee, B.Sc.

The Secretary: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2.

Cambridge Radio Group

Date: May 13. Time: 6.30 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: "Crystal Valves."
By: B. Bleaney, M.A., D.Phil., J. W. Ryde, and T. H. Kinman, M.B.E.
Secretary: D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.

South Midland Centre

Date: May 5. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: "Industrial Applications of Electronic Techniques."
By: H. A. Thomas, D.Sc.
Secretary: H. Hooper, c/o. Central Electricity Board, 53, Wake Green Road, Moseley, Birmingham, 13.

Southern Centre

Date: May 21. Time: 7 p.m.
Held at: The Admiralty Signal Establishment, Haslemere.
Lecture: "The Development and Study of a Practical Spaced-Loop Radio Direction-Finder for High Frequencies."
By: W. Ross, M.A.
Secretary: W. M. Read, The Oaks, Ashurst, Southampton.

The Television Society *

Date: May 9. Time: 6 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: "Television Picture Quality."
By: C. L. Hirshman.
Secretary: G. Parr, 68, Compton Road, Winchmore Hill, N.21.

Hull Electronic Engineering Society

Date: May 9. Time: 7.30 p.m.
Held at: Ferensway Showrooms.
Lecture: "Luminescence in Low Power Discharge Lamps."
By: Mr. Smith.
Hon. Secretary: C. W. Wyan, 2, Lockton Grove, Calvert Road, Hull.

The British Sound Recording Association

Date: May 30. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2.
Lecture: "Sound on Film and the Amateur."
By: D. O. Roe, B.Sc.
Hon. Secretary: R. W. Lowden, 3a, Pembroke Buildings, Camberley, Surrey.

The Institution of Electronics
North-West Branch

Date: May 16. Time: 6.45 p.m.
Held at: Reynolds Hall, College of Technology, Manchester.
Lecture: "Radar Navigation."
By: A. Levin.
Secretary: L. F. Berry, 105, Birch Avenue, Chadderton, Lancs.

British Kinematograph Society
Theatre Division

Date: May 18. Time: 11 a.m.
Held at: The Gaumont-British Theatre, Film House, Wardour Street, W.1.
Lecture: "Sound Reproducing Equipment."
By: H. J. Odell, A.M.I.E.E., and A. T. Sinclair.
Secretary: R. H. Cricks, Dean House, Dean Street, London, W.1.

Radio Societies

Cheadle (Staffs) and District Amateur Radio Society

Classes have already started in the following subjects: Morse, elementary theory, receiver theory and design, transmitter theory and design, aerials, and workshop practice and measurements.

Tutors are qualified wireless officers, and the club now has thirteen licences to its credit.

The first annual Ball is to take place on May 23. Details may be obtained from:
Hon. Secretary: J. Hughes, Abbots Haye, Cheadle, Staffs.

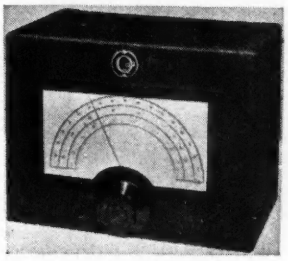
Exeter and District Amateur Short Wave Radio Society

A series of interesting lectures is being prepared on every branch of Radio. A hearty welcome to the Society is extended to all short wave enthusiasts.
Hon. Secretary: E. G. Wheatcroft, 7, Mount Pleasant Road, Exeter, Devon.

North-West Kent Amateur Radio Society

Meetings will continue throughout the summer and will be held on the last Friday of each month at Aylesbury Road School at 8 p.m.
Hon. Secretary: L. Gregory, 18, Upper Park Road, Bromley, Kent.

BERRY'S
(SHORT WAVE) LTD
for Quality components



"Q-MAX" V.H.F. CONVERTOR
embodying circuit refinements not found in any other make, plus advantages of—
MONO-UNIT COILS
Full Vision Calibrated Scale: One knob tuning and Extra Top Band Coil Range.
Price (with 30Mc/s or 56Mc/s Coil Unit) **19 Gns.**
(Extra Coil Units 30/- each).

"Q-MAX" CHASSIS CUTTERS
Holes cut easily and cleanly, without distortion of the metal.
1¼" (Octal) 10/6
1½" and 1¾" 12/6
Postage 9d. extra.
(Patent Applied for).

ABSORPTION WAVEMETER AND PHONE MONITOR
All amateur bands are by means of plug-in inductances 35/-

Obtainable from your local Q-Max dealer or direct from:

BERRY'S (SHORTWAVE), LTD.
25, HIGH HOLBORN, LONDON, W.C.1
(Opposite Chancery Lane) *Tel: HOL 6231*

'Illustrated Catalogue "E.E."
Price 6d. Post Free.

BOOK REVIEWS

Electrical Transmission in Steady State

P. J. Selgin (McGraw-Hill, New York, 1946) Price in Britain, 25/-, ix + 427 pp. 100 figs.

This book must be approached cautiously; it would appear from the Preface that it is intended mainly for those who already have some knowledge and experience of transmission problems, and it is certainly not a book for the beginner. But to a more mature reader it will be a stimulating book, and can be highly recommended. The treatment is mathematical, but does not require an advanced mathematical knowledge. Great emphasis is laid upon graphical methods and the use of charts or maps of complex functions as a means of saving time in the solution of actual problems.

The title does not adequately indicate the nature of the subject-matter. Broadly, the subject covered is the steady-state response and utilisation of communication lines and networks, almost exclusively from the point of view of high frequencies such that the physical length of a line may be short although the electrical length is long. The telephone engineer, expecting a treatise on cables and networks for use in cable communication systems, is likely to be severely disappointed. For instance, Chapter IV is headed "Distortion in Transmission Lines," and dismisses this subject in less than seven pages; the whole problem of leading and loaded lines is allotted two inches of text! But the treatment of h.f. transmission lines is very good and the use of lines as transformers and for tuning is made quite clear. Electromagnetic theory is introduced half-way through the book, and is applied to further line problems and also to circuits.

While admiring the book as a whole, the reviewer must confess to a certain irritation, likely to be shared by most experienced readers, caused by the author's desire for new terminology at any cost. "Decibel drop" is used to mean the voltage ratio in decibels measured across unequal impedances; "matching" is used for giving the correct load impedance to an *iterative* network; "frequency number" is used for the ratio of frequency in rads/sec to velocity in miles/sec, which really has the dimension $[\text{length}]^{-1}$; and the word "generic" (e.g. as in "generic terminations") occurs countless times with a meaning that can only be guessed at. The loss terminology of Chapter VI is likely to worsen the present confusion of terms in this field.

To sum up, the book is well worth reading; one can profit greatly from the new information it gives, and if occasional irritation is caused, it at least stimulates one to think about the problem—a process which is always useful.

D. G. TUCKER

Principles of Radar

M.I.T. Radar School 2nd Edition. McGraw-Hill Book Co. 25s.

The phenomenal rate at which radar was developed during the war and the great diversity of techniques employed, even in the simplest radar devices, make it difficult for the newcomer to the subject fully to appreciate the many papers on radar systems and equipments that continue to appear in technical journals. There has been, therefore, a need for a good text-book expounding the basic technical principles of the subject with only illustrative reference to particular equipments or systems. This need is now largely met by this book, which is written by the staff of the radar school of the Massachusetts Institute of Technology.

The book was in the first instance prepared to supplement courses of instruction given during the war, but it is now published after revision in the light of war time teaching experience. The result is a lucid account of the essential branches of radar theory which should be of great value both to the radar- and the radio-engineer. The book comprises twelve chapters, the first of which surveys radar principles in broad outline, whereas the remaining chapters each deal with a specific branch of the subject. Chapter II on timing circuits treats pulse forming circuits of a variety of types and Chapter II discusses cathode ray tubes and the associated time-base circuits required for the various forms of display used in radar.

These chapters should be of considerable interest to the television engineer. Chapter IV considers the problems of receiver design at ultra high frequencies and microwave lengths with particular reference to the significance of receiver noise. Chapters V, VI and VII cover radar transmitting valves—magnetrons and triode oscillators—and the methods of modulating them for pulse operation.

A useful account of the theory and practice of high frequency transmission lines in radar is given in Chapter VIII which includes the theory and the use of the circle diagram and Smith chart. Aerial theory receives thorough treatment in Chapter IX which discusses input impedances, beaming on metre and microwave lengths, and other topics. There is a useful section on the propagation of electromagnetic waves at radar wavelengths and the factors which influence it, such as earth reflexion and atmospheric refraction.

Chapter X is an account of wave guides and resonators and their uses in radar. The treatment is elementary but rigorous with emphasis on the practical techniques that have been developed during the war. Chapter XI comprises an account of T.R. systems, those ingenious devices that permit a single aerial to be used alternately for transmission and reception of radar pulses at a rapid recurrence rate.

The final chapter discusses synchros and servomechanisms which are important for automatic following in certain radar equipments.

This summary of contents serves to indicate the wide range of technical knowledge required for a satisfactory understanding of radar and also to suggest that this book should be of great value not only to the radar engineer but to light-current engineers in general. It should cause little surprise that the principal radar research establishment in this country as well as that in the United States should have found it necessary to supplement its research effort with an intensive educational effort.

The book is written objectively with no attempt to attribute individual contributions to specific persons, but it should be recalled that British and American radar knowledge was pooled and that a great many of the new principles and devices described in the book are in fact of British origin.

The book is profusely illustrated with good diagrams.

L. G. H. HUXLEY

Books reviewed in this Journal can be obtained from

H. K. LEWIS & Co. Ltd.
136 Gower Street, W.C.1

If not in stock, they will be obtained from the Publishers when available

Technical Dictionary—English, German and French

Hans Thali (H. Thali and Co., Switzerland. 18.75 fr.).

This is a well-printed and well-bound dictionary of terms used in electrical engineering, radiocommunications, and some allied subjects. It is marked "Vol. 1," but the compiler does not state its relation to other volumes to appear.

The difficulties of exact translation of some technical words is appreciated, and short explanatory notes are included where ambiguity makes them necessary. There is also a useful appendix of English abbreviations and tables of constants.

The book can be recommended as a useful addition to the radio engineer's

library and it is hoped that its reception will encourage the publishers to issue an Italian and Spanish dictionary in the same style.

G.P.

The Vector Operator "j"

F. C. Gill. (Pitman). Price 7s. 6d. 61 pages, 32 figures.

The object of this booklet is strictly limited, viz., to familiarise the electrical power engineering student with the use of the operator 'j.' The author succeeds in his aim, and there is no doubt that, after reading the text and working out the examples, the student with no previous knowledge should be able "to use the method with skill and confidence."

There are four chapters, and an appendix giving answers to the specimen questions appearing at the end of each chapter.

Chapter 1 explains the derivation of the 'j' operator, and its use in defining a vector as a complex quantity. Addition, subtraction, multiplication and division of complex quantities completes this section. The author takes the unusual course of defining the angle of the vector in terms of the smallest angle it makes with the horizontal axis, i.e. angles of 120° and 200° by normal convention are given as 60° and 20° respectively. There is, of course no reason why a break with convention should not be made, but it should only be undertaken if it reduces confusion for the reader. This cannot be claimed for the author's convention.

Although single phase series and parallel circuits are the subjects of chapter 2, one example uses a 3-phase load, and another employs two transformers coupled to a common load. The latter makes a rather complicated example for the elementary student, to whom the book is most likely to appeal; much of this difficulty would disappear if Fig. 16 showed the open-circuit secondary voltages as generators in branches A and B. The 3-phase load example would be better placed in chapter 3, which deals with problems on 2- and 3-phase networks.

The final chapter gives the alternative methods of expressing a vector in exponential, trigonometric, and modulus-argument form, and shows their interrelationship and connexion with the 'j' form. Many illustrations of this are given.

It is a pity that the publishers had not spent less money on the cover and more on the paper, diagrams and format. "Therefore" (∴) signs too liberally besprinkle the text.

After reading this booklet one could hazard a guess that its sale will be as limited as its scope. In price and content it cannot compete with many similar books, which contain not only an adequate treatment of the operator 'j,' but also provide the student with the much wider knowledge of mathematics required by the electrical engineer and, in particular, the radio specialist.

K. R. Sturley

Television Receiving Equipment

By W. T. Cocking, M.I.E.E. Second Edition Published for "Wireless World" by Iliffe & Sons, Ltd. 380 pages, 210 illustrations. Price 12s 6d. (postage 5d.).

This new post-war edition of one of the first British books on television has been eagerly awaited by radio technicians everywhere. In so far as Great Britain still leads with television service operating on a regular schedule, this volume will be welcomed as a valuable contribution to the literature on the practical technicalities of the subject.

The author, for many years associated with *Wireless World* is also editor of *Wireless Engineer* and is well known in technical circles for his lucid style.

Although there have been no fundamental changes in British commercial television practice since the war ended, there have been a number of important detail improvements in technique and these are completely covered by the author in 48 additional pages.

Logarithms Made Easy

H. Webb (University of London Press), 1/3d., net. 28 pp. incl. tables.

The author of this booklet has paid particular attention to the subject of the characteristic, which, he points out, is the stumbling block to many students learning logarithms.

The confusing rule about "one more" or "one less" is avoided by initial conversion of numbers to the standard form, e.g. $1790 = 1.79 \times 10^3$. There are numerous worked examples which help to clarify the intricacies of negative characteristics, but it is suggested that another page might be devoted to these with advantage. The raw student would also be encouraged if a short preliminary note on the origin and advantages of logs. were included—it is not very clear to him why he wants to buy the book. But perhaps this should be left to the teacher.

G. Parr

British Radio Components Catalogue

The British Radio Component Manufacturers have just issued a comprehensive catalogue of their products for distribution amongst overseas customers.

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ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Characteristics and Possible Applications of Silicones

Characteristics of the silicone group of products are briefly discussed, and possible applications of the various types of silicones are indicated. Examples are given of the heat resistance properties of silicone wire enamel, and of its use in machine windings. Uses of liquid silicones referred to include the following: as hydraulic fluids at low temperatures; treating of ceramic surfaces to prevent wetting, and to maintain a high surface resistivity; and as lubricants in the moulding of rubber and plastics.

Electrician, February, 1946. p. 1,666.*

Oscillograph Study of Dielectric Properties of Barium Titanate

(A. de Bretteville)

Results of measurements of the variation of dielectric properties of barium titanate by bridge methods are briefly reviewed. These indicate that, as the substance behaves as a ferroelectric material and hence constitutes a non-linear circuit element, the true dielectric properties cannot be measured by this method. An alternative method is described whereby the whole charging and discharging cycle may be analysed from oscillograms. The temperature range for which test results are presented is from $-175°$ to $+140°$C, at field strengths of 59, 134, 234, 580, and 4,300 volts per cm.

—*Amer. Ceram. Soc. Jour.*, November, 1946, p. 303.*

Anodic Oxidation

(J. Herenguel and R. Segend)

Factors governing the production of a homogenous film on alloys of aluminium by anodic oxidation are discussed. Current density, bath temperature, and film thickness are critical in deriving the optimum conditions for obtaining successful wear-resisting anodic films. Other controlling factors are indicated such as the concentration of the electrolyte and the nature of the alloy to be anodised. Tables are given comparing the thickness of the oxide films which are formed on pure aluminium, aluminium-magnesium alloy, and duralumin. The latter is most difficult to anodise successfully due to the heterogeneous structure of the film produced.

—*Metal Ind.*, January, 1947. p. 3.*

Photoelectric Dust Meter

(G. F. Barnett, A. L. Free)

A dust meter is described in which an indication of the density of dust particles in an air stream is obtained by measuring the intensity of light reflected from the particles by means of a photoelectric device. A system in which the efficiency of an air-cleaning device is measured by comparing the densities of dust in the ingoing and outgoing air flow is also discussed.

—*Electronics*, December, 1946, p. 116.

THERMIONIC DEVICES

The Betatron

(W. Bosley)

An account is given of the development of the Betatron, the fundamental theory of its operation, and its applications. Construction and design of the Kerst 2 MeV and 20 MeV Betatrons are discussed and later developments indicated. Applications of the Betatron considered are as follows: (a) radiographic inspection of metals, (b) deep X-ray therapy for cancer treatment; and (c) research in nuclear physics. Other types of particle accelerators referred to include the Synchrotron and the Microtron.

—*Jour. Sci. Inst.*, December, 1946, p. 277.

The Effect of Grid-Support Wires on Focusing Cathode Emission

(C. Yeh)

In an earlier paper, Thompson has shown experimentally that sharp electron beams can be obtained if the relative electrode potentials on the anode and the grid of a vacuum tube are properly adjusted. However, theoretical interpretation of this effect was lacking. In the present paper the effects of the grid-support wires and of the various tube dimensions on the angle of electron emission are investigated theoretically. The investigation indicates that Thompson's interpretations are in the right direction. Quantitative check with the experimental results cannot be expected because the theoretical computations are based upon pure electrostatic considerations at the cathode surface, while in actual experiments the angle of beam current at the anode is measured. Thus, the focusing and defocusing effects of the field distribution in space and the space charge existing near the cathode will cause a wide deviation between the angle of electron emission at the cathode and that of the beam current at the anode.

—*Proc. I.R.E.*, July, 1946, p. 444.

CIRCUITS

The Multiple Resistances of *N* Resistors

(L. Dunbar).

Mr. N. W. Lewis has shown† that if the values of three resistors are three consecutive terms of the geometric series in which each term is the sum of the three preceding terms, then the distribution of the 17 resistance values attainable by various combinations of the resistors is closely related to another geometric series with a common ratio not exceeding 6:5, covering approximately a decade in 16 steps.

In this paper it is shown that as the number of resistors is increased the ratios between consecutive steps can be arranged to become increasingly more uniform without exceeding the same 6:5 ratio, but over an extended range. Alternatively, increased uniformity can also be obtained with more steps of lower consecutive ratio value.

Tables are worked out for four and five resistors respectively. These are followed by a short summary of the results obtained and a brief analysis of the general properties of the λ-series (λ being the common ratio of the geometric series).

†*Jour. I.E.E.* 1945, Pt. I. p. 378.—*Jour. I.E.E.*, November, 1946. p. 533.

Equivalent Capacitances of Transformers

(W. T. Duerdoth)

The paper shows that the distributed capacitances between windings or windings and screens, of transformers may be represented by lumped capacitances, provided that the magnetic coupling between the turns of a winding is perfect. Expressions have been obtained for the equivalent capacitances of a number of different arrangements including windings in layers, sections with screens.

—*Wireless Engineer*, Vol. 23, June, 1946, p. 161.

A Method of Increasing the Range of V.H.F. Communication Systems by Multicarrier Amplitude Modulation.

(J. R. Brinkley)

The initial development of a method of extending the range of improving the coverage of V.H.F. communication systems of the type used for police services is described. The method is based on the simultaneous amplitude modulation of a number of carriers closely spaced in frequency. The frequency spacing between the carriers is so chosen that they lie within the band-width of the V.H.F. receiver, without producing audible interaction components of importance.

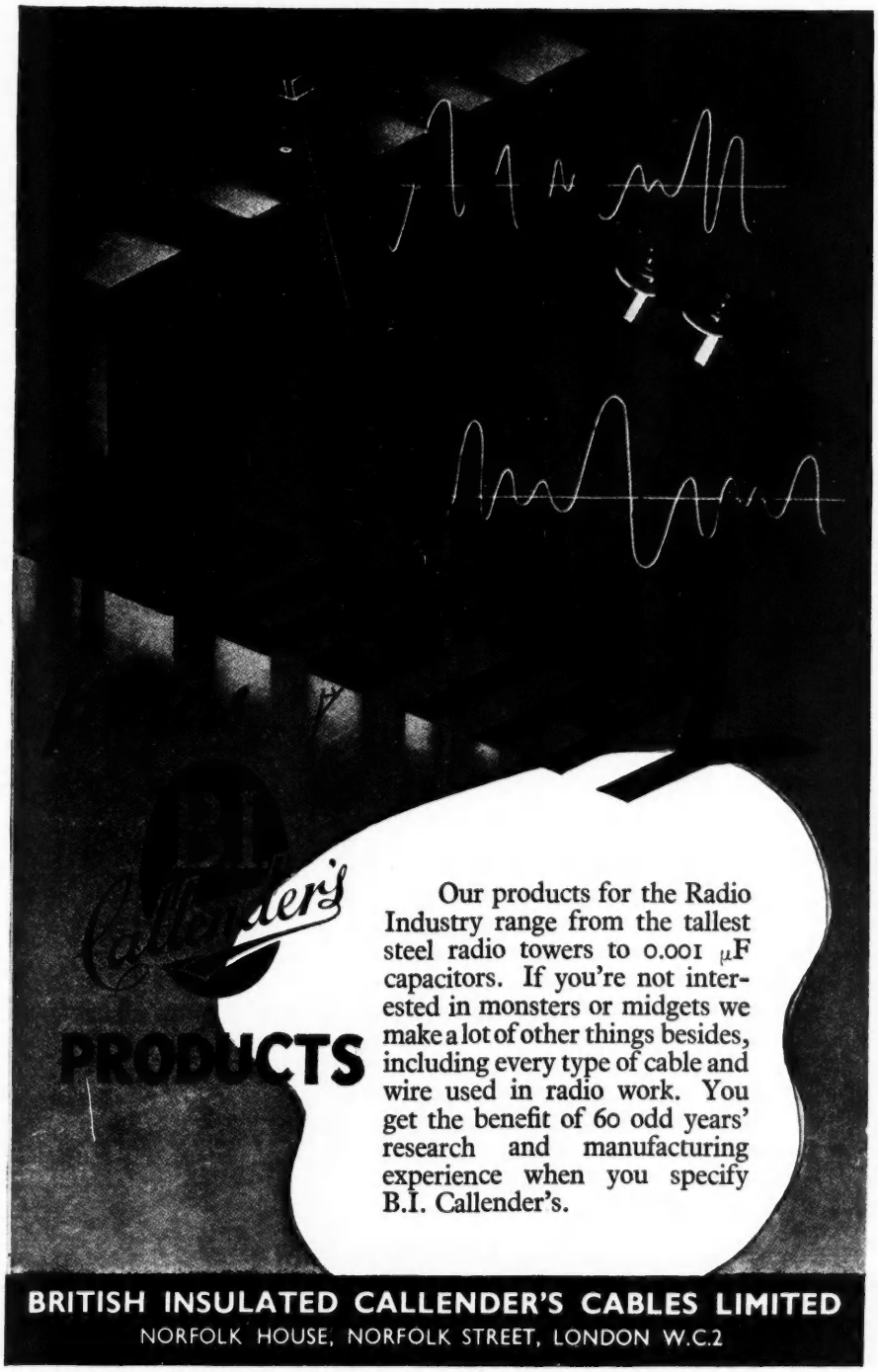
Two-carrier schemes employing separate transmitters at the same site have been found to give improved coverage, while two- and three-carrier schemes using separate sites have been found to give greatly increased range.

An unsuccessful attempt to achieve the same object with frequency-modulated transmitters using the same nominal carrier frequency is described. The difficulties of employing frequency modulation with common modulation are discussed and considered to be fundamental.

Single-station V.H.F. schemes upon which the development of the multi-carrier scheme is based are briefly described.

—*Jour. I.E.E.*, Vol. 93, Pt. 3, May, 1946, p. 159.

* Abstracts supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester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Engineering and Science Degrees for Ex-Servicemen

THERE are many competent engineers who have been unable to obtain degrees, largely as a result of war service either in the Services or in industry under conditions which did not permit them to have the necessary time to study for degrees. Many of these men are very competent indeed and are quite capable of carrying out research or development work without technical guidance. Nevertheless, their future career would benefit greatly if they were able to obtain a degree.

The majority of these engineers, whose age in general lies between, say, 25 and 30, have gained sufficient knowledge and experience to enable them to pass Inter. with very little difficulty, but there is at the moment, so far as I have been able to ascertain, no course of study which is convenient for a large number of them, especially in view of the fact that industry is now spread throughout the country to a very much greater extent than before the war, while educational facilities are still limited to large centres of population. This, together with the fact that a five-day week is now fairly general, makes it more difficult than ever to obtain the necessary extra time for travelling considerable distances in order to go to evening classes or to obtain a full day off every week.

It is suggested, therefore, that it might be practicable to arrange courses of study at a number of technical colleges throughout the country, either in the form of a full day on Saturday or a half day on Saturday and, say, one or at most two evenings per week. In this respect it should be borne in mind that engineers and physicists of the grade referred to often require to visit their professional institutions for lectures and, therefore, at least one extra evening per fortnight is likely to be occupied at such gatherings.

If those engineers or physicists who are interested in such a proposal would care to communicate with the writer, he will, if the numbers prove to be sufficient, undertake to communicate with the Ministry of Education on this subject in order to ascertain whether something can be done to meet their wishes. In this respect would they please state name, address, whether it is desired to take a degree in physics or in engineering and state the name of the nearest technical college at which it is desired to attend and whether all day Saturday or part of Saturday and two evenings is preferred. In order to enable such courses to commence in September of this year immediate action is required and, therefore, an early reply would be appreciated.

The following two types of course are proposed and replies should state which course is applicable:

(1) A two-year course, leading to final B.Sc. or B.Sc.(Eng.), for engineers who have already passed Inter. or who will be able to pass Inter. this year.

(2) A similar course starting in September but lasting, say, three years for those who would be able to pass Inter. next year.

It will be appreciated that the Ministry of Education, to whom a copy of this letter is being sent, cannot be expected to provide such courses unless a genuine need for them exists.

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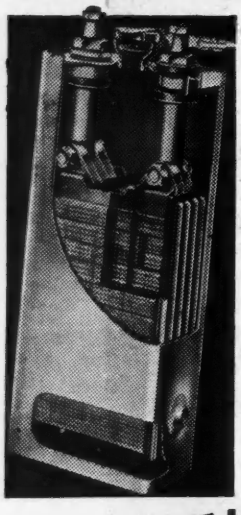

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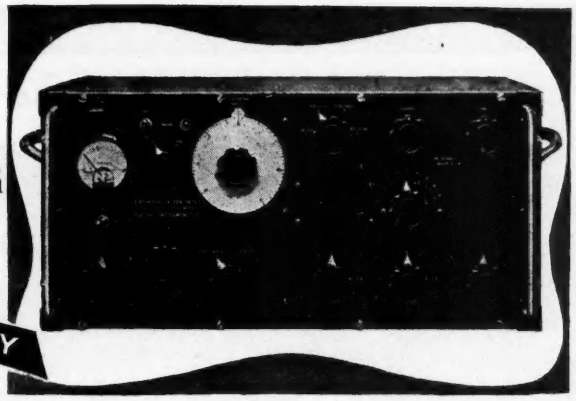

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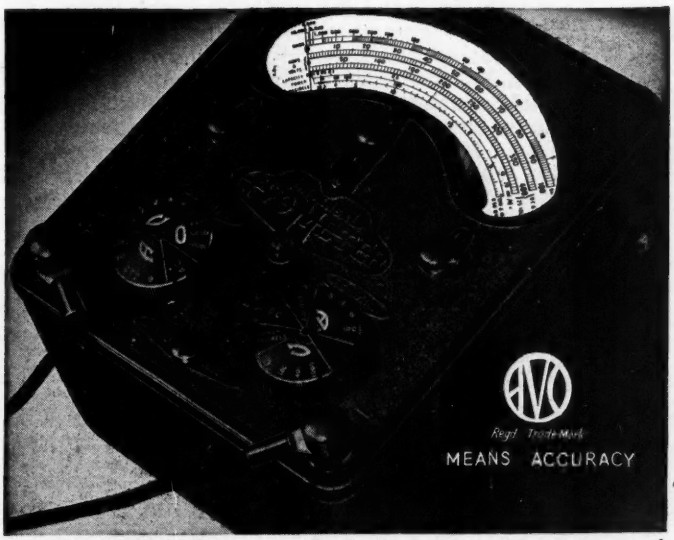

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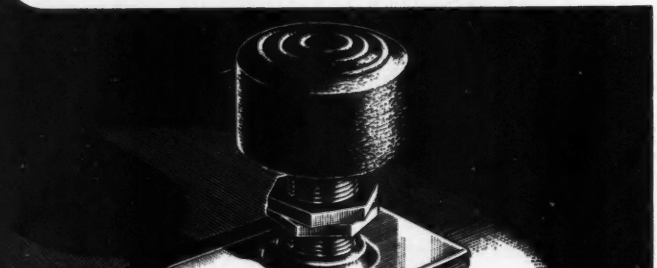

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PUBLIC APPOINTMENTS

THE HOME OFFICE invites applications from men under 42 with experience of very high frequency wireless for the post of senior wireless engineer in its communications directorate. Salary, £650–750, plus consolidation addition of £90. Candidates should possess professional qualifications in electrical engineering or equivalent experience. Application forms and fuller details of the Service may be obtained from the Establishment Officer (Room 307), Home Office, Whitehall, S.W.1. Completed application forms must be returned to the Home Office **not later than** May 31, 1947.

THE HOME OFFICE invites applications from men between 21 and 51 with experience of Very High Frequency Wireless for the following permanent and pensionable posts in its Regional Wireless Service:—
Regional Wireless Engineer, salary £620—£710;
Chief Wireless Technician, salary not less than £420 at age 30, £570; Senior Wireless Technician, salary £375–£475; Wireless Technician, salary £280 (at 25), £370.
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(India) 10 Underhill Lane, Delhi.
(Egypt) 8 Sharia Tolumbat, Garden City, Cairo.
(Germany) c/o 2nd. Echelon, G.H.Q., B.A.O.R.
Completed application forms must be returned to the Home Office not later than 31st May, 1947 for candidates in the United Kingdom and by 31st July, 1947, for candidates overseas.

BRITISH BROADCASTING CORPORATION. Applications are invited from men (British) for a senior post in the Acoustics Section of Research Department based in London. Applicants should possess a University degree and have a knowledge of physics and electronics. A good knowledge of music is essential as acoustical experimental work in connexion with all types of musical combinations will be involved. The duties include research on acoustical design of studios and investigations into the acoustical properties of materials and structures. Previous experience in acoustical investigation would be an advantage. Commencing salary will be dependent on qualifications and experience, and subject to favourable report will rise by annual increments to a maximum of £890 per annum. Applications stating age, qualifications and experience should reach the Engineering Establishment Officer, Broadcasting House, London, W. 1. within fourteen days of the appearance of this advertisment.

BRITISH BROADCASTING CORPORATION. Applications are invited from men (British) for the post of engineer in the recording section of the Research Department based in London. A University degree in physics or electrical engineering(or equivalent qualifications) would be an advantage. Familiarity with low frequency technique is essential and a knowledge of music, sufficient to deal with the "balancing" of the various components of musical combinations for recording purposes, is desirable. Preference will be given to applicants with experience in the design of light electrical and mechanical equipment, and ability to organise development work in the drawing office and workshops. The successful applicant will be employed on research and development work on all aspects of recording and allied low-frequency problems. He will normally work under the supervision of the head of the recording section, but will have ample scope for initiative and originality. Commencing salary will be dependent on qualifications and experience and subject to favourable report, will rise by annual increments of £30 to a maximum of £680 per annum. Applications, stating age, qualifications and experience, should reach the Engineering Establishment Officer, Broadcasting House, London, W.1, within fourteen days of the appearance of this advertisement.

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UNIVERSITY COLLEGE OF SWANSEA. The Council of the College invites applications for the post of Laboratory Assistant in the Department of Physics, who will be required to act as Steward primarily in charge of apparatus for laboratory classes. A knowledge of woodwork, electrical apparatus, etc. and laboratory maintenance would be an advantage. Wages £6 per week rising by annual increments of 10/- to a maximum weekly wage of £7 10s. Applications (stating age and experience) together with copies of two recent testimonials, should be forwarded to the Registrar, University College, Singleton Park, Swansea.

SITUATIONS VACANT

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CLASSIFIED ANNOUNCEMENTS (CONT.)

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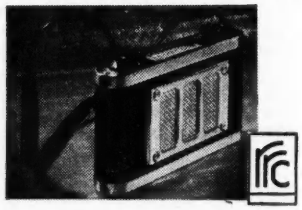

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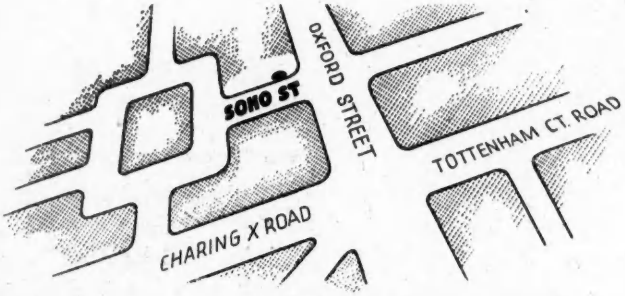

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